VOLS. 82**, 83*, 83bis. PRICE 3s.

A TREATISE

ON

GAS-WORKS.

AND THE

PRACTICE OF MANUFACTURING AND DISTRIBUTING COAL GAS.

BY SAMUEL HUGHES, C.E.

LONDON :—JOHN WEALE.

15. 8. 594

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GAS-WORKS

AND THE PRACTICE OF

MANUFACTURING AND DISTRIBUTING COAL GAS:

WITH SOME ACCOUNT OF THE MOST IMPROVED
METHODS OF DISTILLING COAL
IN IRON, BRICK, AND CLAY RETORTS,

AND OF

THE VARIOUS MODES ADOPTED FOR PURIFYING
COAL GAS.

INCLUDING ALSO

A CHAPTER ON THE HYDROCARBON OR WATER GAS,
AND ON THE RATING OF GAS-WORKS IN
PAROCHIAL ASSESSMENTS.

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CIVIL ENGINEER.

London:
JOHN WEALE, 59, HIGH HOLBORN.
M.DCCC.LIII.

HUGHES, PRINTER,
KING'S HEAD COURT, GOUGH SQUARE.

PREFACE.

SOME apology appears to be due for the delay which has taken place in the appearance of this little volume so long since promised to the public. The author will not repeat the oft-told tale of professional engagements and overwhelming accumulations of business occupying every hour of his time, but prefers to assign the delay to a cause which necessarily applies more or less to the treatment of every popular and progressive subject.

The science of gas-lighting is not one in which descriptions can be furbished up from old forgotten tomes, or condensed from the sparkling and vivaeious volumes of modern writers,—it must be practically inquired into and brought up fully to the standard of the most recent information and most improved modes of working. Such a subject grows as it were even in the author's hands, and not unfrequently he finds himself exceeding alike his allotted time and his allotted space. Sueh has it been in the present case, and yet as some slight compensation for both, the author trusts to show that in some respects he has profitably used the time during whieh the work has occupied him. He has endeavoured in every case to describe new processes and new contrivances with impartiality,

and in such a way as to encourage yet more extensive trials when such appear to be necessary. Without venturing for a moment to entertain the idea that anything contained in this little volume will be new to those who have devoted their life-time to the study of gas engineering, he trusts at the same time that his efforts will not be altogether useless to students who are seeking an elementary acquaintance with the subject, and to the managers and superintendents of gas-works practically engaged at a distance from the Metropolis.

The author takes this opportunity of returning his warmest thanks for the very courteous manner in which his inquiries have been uniformly met. By every officer, from the highest to the lowest, among the Gas Companies to whom he has applied for information, the most obliging attention has been shown, and nothing could be more satisfactory than the manner in which every process was laid open and every part of the works explained.

14, Park Street, Westminster.

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THE MANUFACTURE AND DISTRIBUTION OF COAL GAS.

CHAPTER I.

EARLY HISTORY OF GAS-LIGHTING.

The discovery and earliest observation of elastic aëriform fluids, capable of being inflamed and of imparting light and heat, must undoubtedly have been of great antiquity. The most ancient writings contain notices of inflammable vapours springing from fissures and cavities in the earth. It is evident, therefore, that gas being a natural production, no such human individual as the discoverer or inventor of gas ever existed. Modern chemistry will have no difficulty in showing that all inflammable gases, whether arising naturally from rocks or produced artificially by combustion or otherwise, are composed of very simple elements, and all present a remarkable analogy to the common carburetted hydrogen, which is the gas chiefly burnt in our street lamps and houses at the present day.

Inflammable gas may be truly said to be as old as the first creation of organic matter, for wherever animal or vegetable substances have existed, by the immutable laws of nature they have been subject to decomposition, and wherever decomposition has taken place a variety of gases have been produced, some of them inflammable, and others not so. Whether the decomposition be that caused by the slow combustion of decay or that more rapid process caused by the application of sensible heat, the effect is the same—the gases are equally produced in the two cases.

Gas may with more truth be called a natural production

than steam, although the latter has existed from the first creation of water, and in its palpable state, as proceeding from boiling water, must have been observed in all ages.

The discoveries of man with respect to gas and steam ought rather to be called applications; they are conquests over the elements, the subjugation of great powers in nature to his use and convenience. So it is with nearly all great inventions, in which we find one power of nature after another chained, confined, bound down, stored, and then let loose when required, and made to work machines, to propel ships across the ocean, to supply the place of human labour itself in a thousand variety of ways,—nay to pass far beyond the bounds of human labour, and effect that by a single effort which the manual strength of a whole world could scarcely accomplish.

If such astonishing applications of steam and gas had been made in the days of ancient Greece, what magnificent, all-expressive, world-astounding names would have been found to convey their meaning: instead of such contemptible little monosyllables as *gas* and *steam*, one might have heard of the spirit of coal and the spirit of water, with some superlative adjective to stamp the vast importance of each. In such an age these wonderful conquests would have thrown all meaner efforts into the shade; for them alone would poetry have strung its harp, and the grandest epic productions of genius might have commemorated the victory of man over the inanimate matter of nature, instead of dedicating her loftiest songs to the art of war.

The avidity with which the early nations seized on all natural phenomena and all exhibitions of great natural powers is evident from the veneration paid to the burning flames which issued forth from fissures and cavities in the earth where lakes of petroleum or naphtha existed, or in the neighbourhood of coal or bituminous schists. Some of the earliest nations have considered fire as a type of divinity, and we can scarcely wonder at the feelings of veneration and superstition occasioned by mysterious outbursts of flame whose

origin appeared utterly incomprehensible. Hence Superstition erected her altars over such flames and claimed the interference of the Gods to sustain the perpetual miracle. But all that had been observed with reference to inflammable vapours in ancient times was very far indeed from approaching to anything like a useful purpose. Far from leading to any attempt to collect and use these vapours, their very nature and composition were unknown, and the most mistaken ideas prevailed as to their real elements. It was not till modern chemistry had exploded volumes of ancient dogmas, had traced the so-called elements to far simpler forms, and had taught us the laws according to which elements are combined in order to constitute all forms of matter,—it was not till then that it began to be seen that the inflammable vapour of coal, wood, oils, and other fatty substances was analogous with the marsh gas which arises in bubbles from the decomposition of vegetables under water; that it was of the same nature as the fatal dancing 'Will-o'-the-wisp,' which on the wild moor or bog has lighted many a traveller to destruction; finally, that it was nearly the same as the gas which arises from the decomposition of water, however produced; and that, in fact, one of the constituents of water, the greatest antagonist and extinguisher of flame, was itself the most inflammable substance in nature, namely, hydrogen gas; while oxygen, the other element of water, is the greatest known supporter of combustion.

Many opinions have been hazarded to account for the almost perpetual fires which were kept burning on the ancient altars. Strabo and Plutarch mention these fires, which they describe as constantly burning, to which they add, that they are lighted by invisible means. This seems to involve a contradiction; for if they were always burning, they could not require lighting.

The altar in the Temple of Ægina may be taken as an example of most of the ancient Greek fire-altars as exhibited in the temples. Here a round hole, about 13 inches in diameter, is observed in a block of stone. This round orifice

opens into a square hole, which passes down through solid stone to a depth of several feet. The lower end of the square hole communicates with a cavity in which Mr. Dodwell supposes a fire to have been constantly kept burning, so that the flame did not appear above the surface of the circular opening. He says, nothing more would be necessary than to pour oil into the opening, when the flames would immediately burst forth and appear to have a miraculous origin.

The writings of Herodotus, Ctesias, and Vitruvius, mention the bituminous wells of Zakunthos, the modern island of Zante. Ælian notices springs near Apollonia; and Plutarch, in his Life of Alexander, mentions the fountain of naphtha with fire issuing from the earth in the territory of Ecbatana in Media (the modern Hamadan).*

The Babylonian bitumen, used for cementing masonry, was obtained from the district which now forms the pashalic of Bagdad. Bituminous strata also exist in Switzerland, Germany, France, in the papal territory, in Great Britain and Ireland.

The springs described by Herodotus are not now worked; but their place is defined by the remains of a circular wall about 70 feet in diameter, within which the space is nearly filled up with earth. The opening from which the bitumen was extracted in his day is described as communicating with the sea, which, in calm weather, is tinged with the iridescent colours of the bitumen as it rises up to the surface of the water.

The bitumen is now drawn from small wells about 5 feet diameter and 3 or 4 feet deep. Bitumen was much used by the ancients, not only for mortar but also for cementing reeds together and forming floors and ceilings.

The superstitions of eastern countries have always identified fire with the loftiest attributes of Divinity, and even with

* Dodwell's 'Classical and Topographical Tour through Greece.' London, 1819.

Divinity itself—while traces of fire-worship are said to exist even at the present day. In Plutarch's Life of Aristides there is a passage marking the superstitious reverence which the fire of their celebrated altars enjoyed, where the conquering Greeks under Pausanias are directed by the oracle of Delphi to build an altar to Jupiter the Deliverer, but not to offer any sacrifice on it till they had extinguished all the fires in the country, because it had been polluted by the barbarians (the Persians), and supplied themselves with pure fire from the altar at Delphi. In consequence of this the Grecian generals went all over the country and caused all the fires to be put out.*

The Chinese are said to use at this day, for economical purposes, the gas which escapes spontaneously from beds of bituminous coal. Within 30 miles of Pekin is a coal-field having beds of salt associated with the coal, and streams of gas rising naturally from the coal are conveyed to the salt-works by means of bamboo tubes, and there used for the boiling and evaporation of the salt. Other pipes convey the gas intended for lighting the streets and houses.†

* Extract from Plutarch, relative to the fountain of naphtha in Ecbatana, or Hamadan. Alexander "traversed all the province of Babylon, which immediately made its submission; and in the district of Ecbatana he was particularly struck with a gulf of fire, which streamed continually, as from an inexhaustible force. He admired also a flood of naphtha not far from the gulf, which flowed in such abundance that it formed a lake. The naphtha in many respects resembles the bitumen, but it is much more inflammable. Before any fire touches it, it catches light from a flame at some distance, and often kindles all the intermediate air. The barbarians, to show the king its force and the subtilty of its nature, scattered some drops of it in the street which led to his lodgings; and standing at one end, they applied their torches to some of the first drops; for it was night. The flame communicated itself swifter than thought, and the street was instantaneously all on fire."—'Life of Alexander,' book v. p. 152, Langhorne's translation. 1832.

† R. C. Taylor, on the Coal-fields of China, in the Journal of the Franklin Institute. A similar instance occurs in the village of Fredonia, N. Y., where the inflammable gas issues from a small stream called Canada Way,

There are many other instances at the present day where inflammable gases issue from the surface of the earth: this is the case at several places in the Apennines, particularly near Pietra Mala, on the road from Bologna to Florence. A similar case occurs in a mountain of Lycia, near the shore of the Gulf of Adalia in Asia Minor. Most of these phenomena are supposed to have the same origin as the fire damp of coal-mines, —namely, beds of coal or carbonaceous schists of vegetable formation.

APPLICATION OF COAL GAS TO USEFUL PURPOSES.

We find among the 'Philosophical Transactions' of 1667 a paper by Mr. Shirley, describing a spring arising in the coal district of Wigan in Lancashire, and which was supposed at the time to be a burning spring because the vapour on the surface of it could be inflamed. Mr. Shirley pointed out that it was not the water which burnt, but the gas by which it was accompanied; and he traced the origin of the gas itself to the beds of coal which abound in that part of the country where the spring breaks out.

Although these observations of Mr. Shirley referred the origin of the burning spring to the right cause, and clearly pointed to the possibility of procuring the same kind of gas by the combustion of coal, the subject appears to have received no particular attention at the time. It was not till many years had elapsed that we find another observer prompted by this very same spring to institute experiments of a practical nature on the distillation of coal.

Probably, however, the first authentic record of an experiment on the distillation of coal appears in Dr. Hales' work on 'Vegetable Statics,' published in 1726, where he states that

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over which a gasometer is erected for collecting it.—Brewster's Journal, 1830.

from the distillation of 158 grains of Newcastle coal he obtained 180 cubic inches of air, which weighed 51 grains, being nearly one-third of the whole. This result, which is rather more than 8500 cubic feet per ton, agrees very nearly with the production of gas actually realized from Newcastle coal at the present day.

A few years afterwards, namely, in 1733, we find in the 'Transactions of the Royal Society' a communication from Sir James Lowther, on the inflammable air issuing from the shaft of a coal mine near Whitehaven. The workmen were surprised on sinking to the depth of 42 fathoms to find a rush of air taking place which caught fire from the flame of a candle and burned with great intensity, making a blaze about 3 feet diameter and 6 feet high. Several experiments were made on this flame by the steward and others, who successively caused it to be extinguished by beating it down and smothering it with the colliers' hats and again lighting it. At length the heat communicated by the flame was found to be very inconvenient, as it warmed the pit to a high degree, and it was necessary to have recourse to water in order to extinguish it. After this the gas was not again allowed to be lighted till the sinking had proceeded down to a depth of several feet below the bed of coal through which the gas first made its appearance. The part of the pit at which the gas escaped was then securely walled off, made air-tight, and a tube about 2 inches square extended up the shaft to a height of 12 feet above the surface of the ground. Through this tube the gas was allowed to escape into the open air, which it continued to do in undiminished quantity for several years. Many observations and experiments were made on the gas which was thus discharged from the extremity of the tube. It was collected in bladders, tied up and preserved for many days. When a small pipe was fixed in the mouth of the bladder, and the gas gently pressed out against the flame of a candle by squeezing the bladder, the gas was observed to take fire, and to burn as long as the bladder was gently squeezed. When taken from the candle, after being thus

lighted, it continued burning till all the gas in the bladder was exhausted. This experiment on gas which had been confined nearly a month in a bladder was made in the presence of the Royal Society. It was observed that the gas when it first issued from the top of the tube was as cold as frosty air, and that it would not take fire from a spark, but required a flame to ignite it.

Some thirty years after the attention of the scientific world was thus called to the nature and properties of inflammable gas,—namely, about the year 1765,—we find a proposition made to the magistrates of Whitehaven by the then agent of Lord Lonsdale to convey this same gas through pipes to light the streets of the town. The magistrates, it appears, refused to entertain the subject, although the proposer, Mr. Spedding, proved its perfect practicability by conveying the gas into his own office and using it for the purpose of lighting.

In the 'Transactions of the Royal Society' for the year 1739 is a paper by Dr. Clayton on the subject of distilling pit coal. This paper is an extract from a letter written by the author to the Honourable Robert Boyle, who died in 1691. The letter, therefore, was probably written some time before this, and although not published till 1739 it appears clearly to confer on Dr. Clayton the merit of an earlier experiment on the mode of procuring gas from the distillation of coal than that described by Dr. Hales in 1726.

I shall not quote in detail the experiments concerning the spirit of coal contained in Dr. Clayton's letter to Boyle, as this letter appears in nearly every work on gas which has since been published in this country, and must therefore be familiar to most English readers. Those who may wish to see the complete extract from Dr. Clayton's letter will, however, find it in page 59 of the 'Philosophical Transactions' for the year 1739. The author first gives an account of the ditch near Wigan in Lancashire, described by Mr. Shirley, in which the water was said to burn. He proved, however, the fallacy of this supposition by causing a dam to be made and having the

water below the dam scooped out of the ditch. At first the vapour would not take fire, but on digging down about 18 inches the vapour which arose from a shaly kind of coal took fire from a candle, and continued burning. Suspecting from the proximity of coal the true origin of this inflammable vapour, the Doctor proceeds to say, that he procured some coal and distilled it in a retort over an open fire. He describes the products of his distillation as a *phlegm* which first came over (naphtha), afterwards a black oil (tar), and then likewise a "*spirit* arose which I could noways condense, but it forced my lute or broke my glasses." He discovered accidentally that this spirit (the gas) was inflammable. He then proceeded to collect it in bladders and preserved it in these for the amusement of his friends, before whom he was in the habit of pricking holes in the bladder with a pin and gently compressing the bladder till the small stream of gas took fire at the flame of a candle, when it would continue burning till all the gas was pressed out. It is curious that the process of exosmose was observed at this early stage of experiments on coal gas, for the Doctor says when he filled calves' bladders with the gas it would lose its inflammability in twenty-four hours; he therefore recommends good thick bladders like those of an ox.

The publication of Dr. Clayton's experiments, although they clearly pointed to the practicability of procuring and storing up an inflammable gas derived by distilling coal, appears to have attracted no further notice at the time. No progress whatever appears to have been made in discovery for many years afterwards.

To the celebrated Dr. Watson, Bishop of Llandaff, we are indebted for the first notice of the important fact that coal gas retains its inflammability after passing through water into which it was allowed to ascend through curved tubes. This is noticed amongst other results of Dr. Watson's experiments in the second volume of his 'Chemical Essays,' published in 1767. To this property is due much of the facility with

which the manipulations of a gas-making establishment are carried on, particularly those connected with the hydraulic main and with the purification by means of wet lime.

With the exception of Bishop Watson's experiments, the whole subject of procuring from coal a valuable product in the shape of inflammable gas appears to have slumbered for more than half a century, till about 1790 we find an individual, who was afterwards connected with one of the first engineering workshops in the world, turning his attention to the subject in a truly practical form. This individual was Mr. William Murdoch, then resident at Truro in Cornwall, and afterwards connected for many years with Messrs. Boulton and Watt's establishment at Soho. There can be no doubt as to the exclusive merit of this gentleman, whose claim is unquestionable to the first practical application of artificially manufactured gas to the purposes of lighting. From his own narrations, written with all the earnest simplicity which commonly attends the development of great ideas, it even appears doubtful whether he was acquainted with the papers of Dr. Clayton already alluded to. It is also satisfactory to find that the pre-eminent claim of Mr. Murdoch is most clearly and distinctly confirmed by the celebrated Dr. Henry, that brilliant philosopher whose researches into the nature of aëriform fluids have gained for him the admiration of all Europe.

It appears from Dr. Henry's statement, that in 1792 Mr. Murdoch actually lighted his own house and office at Redruth with gas. He distilled the coal in iron retorts and conveyed the gas through tinned iron and copper tubes to a distance of 70 feet. He used portable gas, carrying it about with him in a bladder, or in bags of leather or varnished silk, and also in vessels of tinned iron fitted with a small metal tube and stopcock, through which the gas issuing from a minute orifice was ignited, and made to serve as a lantern in travelling backwards and forwards between the mines and his own house. He is said to have excited the unbounded astonishment of the country people, and to have confirmed them in the belief that

he was a real wizard, by travelling in a steam carriage lighted up at night with gas contained in bladders. Mr. Murdoch also at this early period made many experiments on various kinds of coal, as the Swansea, Haverfordwest, Newcastle, Shropshire, Staffordshire, and some kinds of Scotch coal. He also tried numerous forms of burners, varying in many ways the shape and disposition of the orifices for the admission of the gas. Thus in some burners the gas was allowed to issue from many very minute openings, forming a rose like the head of a watering-pan, while in others it was thrown out in long thin sheets, and again from circular openings on the principle of the argand burner. His attention was also directed to the necessity for purifying the gas, and he certainly adopted the expedient of passing it through water, but does not appear to have made use of lime, the first application of which, to the purpose of purifying, appears due to Dr. Henry and Mr. Clegg. Mr. Murdoch pursued his experiments on the gas from coal, peat, wood, and other inflammable substances, at such intervals of leisure as his numerous other avocations would permit, till in 1798 we find him lighting up a part of the Soho manufactory and exhibiting his experiments on artificial lighting to numerous persons who are still living and can attest his early labours. At the general illumination for the Peace of Amiens, in 1802, a part of the Soho manufactory was lighted with gas, and this was probably the first public exhibition of the new method of lighting.

Between this period and the year 1805, when a minute account of his discoveries and experiments in gas-lighting was read before the Royal Society, Mr. Murdoch appears to have further advanced the application of gas to useful purposes by lighting up the whole of the workshops at Soho, and also erecting an apparatus for the same purpose at the cotton-mills of Messrs. Phillips and Lee, at that time the largest cotton-mills in Great Britain. The quantity of light supplied to these mills was equal to that yielded by 2000 mould candles of six to the pound, or about 2500 cubic feet per day on the average

of the whole year. To produce this quantity he used 7 cwt. of Wigan cannel coal, yielding at the rate of 7143 cubic feet of gas per ton of coal, considerably less than the quantity made at the present day from the same coal. In his paper of 1805, which was published in the 'Transactions' for 1808, Mr. Murdoch does not particularly describe the process which he followed in making the gas, but merely states that the coal is distilled in large iron retorts, and that the gas, as it issues from them, is conveyed by iron pipes into large reservoirs or gasometers, where it is washed and purified previous to its being conveyed through other pipes or mains to the mills. He describes the burners with some minuteness: these were of two kinds, one on the principle of the argand lamp and resembling it in appearance; the other a cockspur burner, consisting of a small curved tube with a conical end, having three circular apertures or perforations about one-thirtieth of an inch in diameter, one at the point of the cone, and two lateral ones. The gas issuing through these apertures forms three divergent jets of flame, somewhat like a *fleur-de-lis*. The whole of the burners erected in the cotton-mills amounted to 271 argands, each of which gave a light equal to four mould candles of six to the pound, and 633 cockspurs, each of which gave a light equal to two and a quarter of the same candles. The quantity of tallow consumed by each candle was at the rate of four-tenths of an ounce, or 175 grains of tallow per hour.

In his details of the comparative cost of lighting this establishment with gas, as compared with candles, Mr. Murdoch's comparison is very much in favour of the former. Taking an average of two hours per day throughout the year, the expense of candles would be £2000 per annum, while the cost of gas, including every expense of wear and tear and interest on capital, did not exceed £600 a year. On an average of three hours per day, the comparison is still more in favour of gas, the expense of candles in this case being £3000 a year, while that of gas, estimated as before, would only amount to £650.

During his experiments, and in erecting his earlier apparatus, Mr. Murdoch tried various forms of retorts, which will be more particularly noticed in the chapter on this subject, so that it may be sufficient to observe that the earliest forms were upright, with various contrivances for extracting the coke which remained after the expulsion of the gas. Many inconveniences attended this form, as well as an intermediate form, in which the retorts were placed in a diagonal or inclined position. In time all the other contrivances gave place to the horizontal retort, which is the mode of setting almost universally adopted at the present day.

The success of Mr. Murdoch's new mode of lighting the cotton-mills of Lancashire appears to have enlisted a host of ingenious and speculative persons, who entered eagerly upon the course now open before them. About the years 1804 and 1805 we find the subject taken up by eminent chemists, such as Dr. Henry of Manchester, who ably illustrated the mode of making gas in his lectures, and showed how readily and economically it might be used as a substitute for oil and candles. At this time also we find Mr. Clegg, another able mechanician, also engaged in the same establishment as Mr. Murdoch, where he entered as a pupil of Messrs. Boulton and Watt, devoting all his energies to the mechanical appliances connected with the successful application of gas.

Mr. Northern of Leeds, Mr. Pemberton of Birmingham, and Mr. Accum were actively engaged at this time in experiments on coal gas, and the means of procuring it and applying it to lighting purposes. Many of the contrivances and suggestions of these gentlemen were highly ingenious, and they each exhibited before the public gas-lights produced from apparatus of their own erection. The apparatus was of course on a very limited scale, and it does not appear that any intermediate process was practised between the retort and the burner, except that of washing the gas by passing it through water so as to condense and cool it before entering the gasometer. Amongst the individuals who at this time figured as prominent

advocates of the new mode of lighting was Mr. Winsor, a gentleman of most extravagant and magnificent views, who, in public lectures and pamphlets, employed all the arts of unwearied panegyric to gain over the public opinion in favour of lighting by gas. He is even said to have claimed the invention for himself, and to have referred to his own lamps in Pall Mall as evidence of his claims. It appears that Mr. Winsor was delivering public lectures on the subject of gas-lighting at the Lyceum Theatre in the years 1803 and 1804, when he explained the mode of conveying gas through houses, and exhibited many contrivances for burning it in chandeliers and otherwise. He, however, kept back the secret of his mode of manufacturing and purifying the gas.

Although the merit of being an original inventor must be denied to Mr. Winsor, he yet performed excellent service in the cause of gas-lighting by rousing public attention to the subject, an effort in which he displayed considerable talent, joined to unwearied energy and perseverance. This bold and enthusiastic champion of gas-lighting has been termed one of the wildest and most extravagant projectors that ever came before the public. He projected a scheme called the National Light and Heat Company, in which he held out the most unexampled expectations. He gravely declared that an investment of £5 in this company would secure to the fortunate subscriber an income of £570 per annum, and among secondary objects to be effected by the new mode of lighting was the entire abolition of smoke and consequently of chimney-sweeping. The national debt was also to be paid off, and an incredible revenue raised by Government from a tax on the products to be obtained from coal. It will readily be anticipated that all these brilliant hopes evaporated into thin air, and after large sums of public money had been subscribed in answer to the earnest appeals of this sanguine individual, he died poor and neglected, without reaping any of that splendid harvest he so confidently expected.

I have now to introduce another individual, of a widely

different stamp—one who has exercised a most important influence in the mechanics of manufacturing gas, and to whom some of the very best contrivances are due, and some of the most ingenious applications of mechanical skill. This individual is Mr. Clegg, who has been already noticed as a pupil in Messrs. Boulton and Watt's establishment at the time of Mr. Murdoch's engagement there.

Mr. Clegg appears to have struck off in the same direction as Mr. Murdoch, and to have embarked about the same time in the erection of private gas-works for cotton-mills and other establishments. Thus he was engaged in lighting the cotton-mill of Mr. Henry Lodge at Sowerby Bridge, near Halifax, at the same time that Mr. Murdoch was erecting his works at Messrs. Phillips and Lee's mill. Indeed, Mr. Clegg, jun., states, on the authority of his father's journal, that the mill at Sowerby Bridge was lighted a fortnight earlier than the one under Mr. Murdoch's direction.

In the following years, 1807 and 1808, Mr. Clegg proceeded to erect gas-works at various other mills, and at the Catholic College at Stonyhurst in Lancashire, where he first introduced the system of purifying the gas from carbonic acid and sulphuretted hydrogen by passing it through lime in a separate vessel. Previous to this use of a separate purifier, Mr. Clegg had used lime in the tank of the gas-holder, and applied an agitator to keep it in motion. This plan answered very well, except for the difficulty of removing the saturated lime, which eventually led to its abandonment and the adoption of a separate vessel.

The main features in the present system of gas-lighting which are due to Mr. Clegg are the system of wet-lime purification, the hydraulic main, with its contrivance of dip-pipes for isolating the retorts, the present mode of attaching the mouth-pieces to the retorts, and the governor or regulator for adjusting the delivery of gas into the mains; to which must be added the gas-meter in its earliest and most novel form—a contrivance rarely surpassed for simplicity and ingenuity,

and which will claim particular attention at a future page.

These are the principal parts of the mechanism of gas apparatus introduced by Mr. Clegg, and which have become essential parts of the gas manufacture, while there are many other contrivances of perhaps equal ingenuity and merit which are not so universally adopted. Among these are the rotating or web retort, of which a notice will be found further on; the rotative and reciprocating gas-meter, the collapsing gas-holder, and an apparatus for the decomposition of oil, tar, &c. A review of these various inventions undoubtedly places the name of Mr. Clegg in the very foremost rank of those who have advanced the practice and science of gas-lighting.

From about the year 1808, the names connected with gas-works become so numerous, inventions of all sorts and descriptions multiply so fast, and the records of the Patent Office exhibit such a spirit of invention, that it would be impossible to follow them in anything like detail. I must therefore be satisfied with briefly noticing a few of the successive steps by which the practice and science of gas-lighting advanced until it entirely superseded all other modes of public lighting in the metropolis and other large towns, and even came to be extensively used for domestic illumination in place of candles and lamps.

From the year 1809 to 1815 the progress of the new mode of lighting was steadily gaining favour with the public. Many private establishments continued to erect gas-works of their own, and during this period several public gas-light companies were formed, particularly the Chartered Gas-light Company, established in 1809 for the purpose of lighting London and Westminster. Messrs. Winsor, Accum, and Hargreaves were first appointed engineers of this company, and proceeded to carry out the intentions of the directors. It appears, however, that they failed in their attempts to erect works suitable for manufacturing gas, and Mr. Clegg being eventually appointed to supersede them, the works were completed under his direction. In 1813 Westminster Bridge was lighted with gas,

and in the following year the old oil lamps were removed from the streets of St. Margaret's parish, Westminster, and gas-lights put in their place; this being the first parish which applied for a contract to have the streets lighted with gas.

In the year 1814 gas was first applied to the purposes of ornamental illumination. In that year, when the allied sovereigns visited this country, and a general illumination took place in commemoration of the Peace of Europe, the new light was brought into requisition and exhibited to thousands of admiring spectators in illuminating a magnificent pagoda erected in St. James's Park. This building was instantaneously lighted up by a simple contrivance, and in a single instant of time 10,000 lights burst forth and formed an immense and brilliant fountain of fire. In the following year Guildhall was lighted up with gas; and on this occasion the public papers teemed with extravagant praises of the new light. Its mild splendour was described as "shedding a brightness clear as summer's noon, but undazzling and soft as moonlight, altogether forming a magnificent combination worthy the inauguration of the presiding citizen of the great city."

The most active period in the history of gas-lighting is probably comprised between the years 1815 and 1823. In this period many public companies were formed both in the metropolis and in the chief provincial towns. This was also the date of a strenuous attempt to introduce the method of making gas from oils, fats, bitumen, resin, and other materials, according to a patent which had been taken out by Mr. John Taylor in 1815. During the few years which succeeded 1815, several companies were formed both in this country and abroad for the purpose of making gas from oil or from the other materials set forth in Mr. Taylor's patent. Among the principal cities which in this country yielded to the delusion in favour of oil gas were Liverpool, Bristol, and Hull; but in every case, after lengthened and expensive trials, the companies have been

compelled to reject the use of oil and to adapt their works to the production of gas from coal.

The superiority of the gas procurable from oil and such other matters as Mr. Taylor enumerates is unquestionable. It contains a much larger quantity of olefiant gas than the common coal gas, and it had long been known that olefiant gas, containing as it does double as much carbon as ordinary carburetted hydrogen, was by far the most valuable ingredient in any inflammable gas. The gas from oil would also be free from sulphuretted hydrogen, and other impurities which cause considerable expense in the purification of coal gas. In addition to this, the advocates of oil gas contended that the expenses of production and management would be much less than in a coal-gas establishment, and that the large supply of oil required would afford employment to thousands of fishermen, who would be engaged in the capture of fish suitable for yielding oil in sufficient quantity. Of course all considerations of this nature require to be tested by actual practical experience, and when this was applied to the case of lighting by means of oil gas, the results were widely different from those which had been anticipated in theory. It was found impossible to work the establishments with anything like the same economy as those for producing coal gas, and all the companies, without exception, found it was hopeless to expect any dividend for their outlay. Under these circumstances the oil-gas works were abandoned one by one, and apparatus for distilling coal substituted in their place.

In 1819 we find Mr. David Gordon obtaining a patent for compressing gas into suitable vessels fitted with proper valves and capable of being carried about, so as to render the gas portable. This contrivance, which can scarcely be called an invention, as it had been practised by Mr. Murdoch many years before, led to the formation of the 'London Portable Gas Company.' However, after carrying on business some time it was found that the scheme would not answer, and the company was ultimately broken up. About the same time Pro-

fessor Daniell, F.R.S., was engaged in an unsuccessful attempt to make gas from resin. It is said that his apparatus was highly ingenious, but the project on trial was soon abandoned, from inability to compete with coal-gas works. The Act for lighting Bristol with oil gas was obtained as late as 1823, in spite of the warnings of several eminent gas engineers that the project would prove unsuccessful. The truth of these warnings was amply confirmed in the course of a few years.

Such is a brief sketch of the leading historical facts which mark the progress of gas-lighting till within the last 20 years. The chapters which follow will explain the modern system of constructing and working establishments for manufacturing gas from coal. I can only hope, however, to present a fair selection of the various practices and contrivances, which vary very much at different works. A gradual spirit of improvement has characterized the progress of all gas establishments, and improvements made almost imperceptibly year after year have brought their efficiency up to a high standard. This is evidenced in the most practical manner both by the increased produce of gas and by the diminution of price to the consumer. In the Metropolis, few of the Companies now charge more than 4*s.* 6*d.* per 1000 feet for gas, while the price a few years ago ranged from 8*s.* to 10*s.* While most of the general arrangements have remained the same for the last 20 years, more especially those for which we are indebted to Mr. Clegg, a constant succession of improvements in the subordinate parts has vastly improved the value and efficiency of gas-lighting, which in fact has been doubled to the public. It will be seen from the chapter on Retorts that a highly scientific mode of applying heat for the distillation of coal has been gradually effected, and without referring to the combinations of clay and iron retorts, the effects of which are still disputed, it is certain that by successive steps the mode of heating and setting the retorts has reached a high degree of excellence. In the details of the hydraulic main and dip-pipes also, improvements have not been wanting; as an instance of which may be noticed the

employment of wrought iron for the material of the main, instead of the cumbrous and heavy castings formerly in use. The same remarks apply to the purifiers, condensers, gas-holders, and other parts of the apparatus. Again, as connected with the distribution of gas, the modern system of fittings deserves especial commendation when contrasted with the very imperfect mode in which this kind of work was originally executed. The business of the gas-fitter—one of considerable skill and nicety—has been in fact created since the general introduction of gas-lighting. When we consider the difficulty of confining in metallic pipes a subtile aëriform fluid of only half the specific gravity of common air, conveying it into all kinds of corners and all parts of buildings, in addition to the use of innumerable cocks and burners, the delicacy and nicety required in every part of the gas-fitter's manipulation are entitled to considerable admiration; while the advantage he has derived from the beautiful invention of welded iron tubes and pewter-drawn tubes, contrasted with every other form of metallic tubing originally in use, adds considerably to his facilities. Gas may now be burnt in private houses without the slightest effluvia or escape from any of the pipes, joints, or fittings, and if properly purified may be burnt in any kind of room, however highly ornamented by gilding and otherwise.

CHAPTER II.

ON THE CHEMISTRY OF GAS-LIGHTING.

Bodies capable of yielding Gas —Description of the production of Gas during the burning of an ordinary Candle—Derivation of the word Gas—Products from the distillation of Coal.

ALL organic bodies, that is to say, all bodies derived either from the animal or vegetable kingdom, will yield gas when decomposition takes place. When such decomposition is effected by means of heating organic matter in close vessels, the gas may be collected, and when confined so as to be allowed to issue only in a small jet out of a minute orifice, the jet may be ignited and made to burn, so as to give out light and at the same time heat, sufficient to inflame other portions of gas as they issue forth, and so to keep up the continuity of the flame.

The gases so derived are named from the chief constituents of organic bodies: thus we have hydrogen gas, oxygen gas, nitrogen gas, carbonic acid gas,—named from the elements hydrogen, oxygen, nitrogen, and carbon, which constitute the principal part of all organic matter.

We have also gases named from the combination of these elements, either with each other or with foreign bodies, frequently associated with organic matter, as carburetted hydrogen gas, sulphuretted hydrogen gas, carbonic oxide, &c. These names are so expressive that it is scarcely necessary to explain that carburetted hydrogen is a compound of the vapour of carbon with hydrogen, that sulphuretted hydrogen is a similar compound of the vapour of sulphur with hydrogen, that carbonic oxide is the vapour of carbon in combination with oxygen, &c.

Coal and other bodies capable of yielding gas by distillation

are composed chiefly of oxygen, carbon, and hydrogen. When the heat reaches a certain point the combination of these elements is destroyed, and they enter into new combinations, the principal of which are the various gases arising from the distillation. Thus, when one volume of oxygen combines with one volume of carbon, carbonic oxide is formed, and when another volume of oxygen enters into combination an acid gas is produced, termed carbonic acid gas. Again, at one part of the process nearly pure hydrogen gas is liberated, another portion of gas is formed by carbon, combining in the proportion of one volume of carbon to two volumes of hydrogen; and lastly, olefiant gas is the product of equal volumes of carbon and hydrogen entering into combination.

In all the contrivances which have been used for producing light from oleaginous or fatty matters, either in lamps or in the form of candles, the various component parts of gas, as the carbon and hydrogen, are actually vaporized and put into the form of gas before their combustion takes place. In this point of view every wick burning in any kind of lamp or candle is, in fact, a small laboratory for the production of gas, which is burnt or consumed at the instant of its production. It was reserved for the chemistry of our own day to point out this analogy, as it was reserved for the practical skill of our engineers and machinists to bring to perfection the means of producing this gas on a large scale, of storing it for consumption, and then sending it forth whenever required into our streets and houses, to communicate light and enable mankind to pursue its useful and laborious avocations when darkness shrouds the earth, as well as in the light of day.

A beautiful action takes place in the combustion of an ordinary lamp or candle, in which the wick surrounded by flame represents a series of capillary tubes to convey the melted matter in the form of gas into the flame. This action will be very apparent to any one who will watch the process of combustion in an ordinary wax or tallow candle. First, he will perceive a cup of melted matter around the wick, in which

a great number of small globules are seen constantly in progress towards the wick. Many of these globules are also seen standing on the wick, studding it all over like little sparkling diamonds. Let us consider what these globules contain. They are filled with the inflammable gas produced by the heat applied to the melted wax or tallow, but fortunately for the success of this method of burning, these globules do not break and set free the gas until they come into close contact with the flame, when the heat becomes so great that the expansion of the gas causes each little globule to break and add its contents to the already burning flame. How beautiful is this provision! How exquisitely constituted are the properties of matter to cause this beautiful result! In every common candle we behold an apparatus of exquisitely refined ingenuity, in which gas is being enclosed in little microscopic pellicles, which are floated to the base of the wick. There hundreds of these little tiny globules are seen ascending the wick, while hundreds of others are every instant exploding and discharging their contents into the flame which is thus made up by the instant combustion of gaseous matter at the moment when it leaves the liquid form, through the medium of this intermediate stage, in which it assumes the form of an infinitely small translucent globule.

It is obvious if the gas were to be actually formed at the surface of the small cup of melted fluid already spoken of, the surface being usually half an inch below the nearest part of the flame, that the gas would immediately diffuse itself through the air, and combustion could not proceed. It is only through the property which the gas possesses of taking an intermediate form and not finally assuming its gaseous condition till it reaches the flame, that the effect of continued combustion is preserved.

Before proceeding to consider the various products produced by the distillation of coal as practised in gas manufactories, it may be useful to glance at the origin of the word *gas*. The word is very slightly altered from a German monosyllable of

the same sound, signifying the ebullition which attends the escape of aëriform fluids from substances in a state of effervescence.

The gaseous products arising from the distillation of coal may be divided into three classes:—1st, those which are valuable for purposes of illumination, as the olefiant gas and the hydrocarburets or vapours of volatile oil. 2nd, Those which burn with a bluish flame and give out very little light. These are—simple hydrogen gas, carburetted hydrogen, and carbonic oxide. 3rd, The injurious products which require to be separated by purification, not only on account of the evil effects arising from breathing them, but also on account of their injury to colours, &c. These are—carbonic acid, ammoniacal gases, sulphuretted hydrogen, and sulphuret of carbon. Cyanogen is also another product of distillation, due, like ammonia, to the presence of nitrogen in the coal, and when any alkaline matter is present cyanates are frequently found.

I propose to notice each of these products somewhat more in detail. The OLEFIANT or oil-making gas is so named from its property of combining with chlorine and forming an oil. It consists chemically of 2 atoms of carbon united with 2 atoms of hydrogen, its chemical equivalent being $C_2\,H_2 = \overline{6 \times 2} + \overline{1 \times 2} = 14$. Hence 100 parts of olefiant gas contain by weight 85·7 of carbon and 14·3 of hydrogen.

Olefiant gas containing double as much carbon as the ordinary carburetted hydrogen burns with much greater brilliancy and gives out a far superior light, owing to the incandescence of the particles of carbon. When prepared in a state of purity by the chemist, who obtains it by heating spirits of wine with sulphuric acid, the olefiant gas is colourless, neutral, and but slightly soluble in water. When mixed with oxygen it explodes with great violence. Its density is ·981, the weight of 100 cubic inches being 30·57 grains. It is the proportion of this gas present in the ordinary coal gas used for economical purposes which determines the value of the latter. The quantity of olefiant gas present in any given mixture is ascer-

tained by mixing chlorine with the gas in the absence of light, and collecting the product over water, when a yellow oily liquid is produced, which trickles down and settles on the surface of the water, and shortly after sinks down in drops to the bottom. The oil thus formed consists of one atom of chlorine united to one atom of olefiant gas, so that its equivalent is $36 + 14 = 50$. Hence $\frac{14}{50}$ of the product will be the weight of olefiant gas combined, and thus may be ascertained the proportion of it contained in the mixed gas.

Estimated by this test, there are few specimens of mixed gas which contain more than 18 per cent. of olefiant gas and hydrocarburets, while the density of such a mixed gas would not be less than ·640. It is probable that the common gas in every-day use in London does not contain more than 4 or 5 per cent. of olefiant gas with a specific gravity seldom exceeding ·450.

Dr. Henry made many experiments on olefiant gas, the weight of which he found the same as carbonic oxide.

	grains.
According to him a cubic foot weighs	520
And requires for its combustion 3 cubic feet of oxygen, weighing	1800
	2320
The product of combustion is 2 cubic feet of carbonic acid, weighing	1700
And water	620
	2320

The *hydrocarburets* are liquid carburets of hydrogen, the vapours of which enter into mixed gas. These mostly consist of carbon and hydrogen combined in the atomic properties of these bodies, namely in the proportion of six to one by weight. The vapours of the hydrocarburets found in coal gas increase the illuminating power, and impart to it a peculiar odour, which will always accompany coal gas, however completely it may be free from sulphuretted hydrogen.

II. PRODUCTS OF DISTILLATION YIELDING AN INFERIOR DEGREE OF LIGHT.

We now come to the second class of products,—namely, those which give out considerable heat but very little light.

The first of these is pure hydrogen gas, which is most readily obtained for experimental purposes by the decomposition of water. When steam is passed through a red-hot tube, or through iron filings heated to redness, the oxygen of the water unites with the iron, and the hydrogen is set free. This is the most simple and direct process of making hydrogen gas, but not the most easy. If a few pieces of zinc be placed in a jar about half-full of water, and sulphuric acid be added, a curious effect takes place, which for our purpose may be called a decomposition of the water, the oxygen combining with the zinc, and the acid and the hydrogen of the water passing off as gas. I need scarcely allude to the beautiful philosophical experiment of decomposing water by means of voltaic electricity, in which perfectly pure oxygen is collected over the plate connected with the copper extremity of the battery, and hydrogen in a state of equal purity over the plate connected with the zinc extremity.

Hydrogen is the lightest of all the known gases, its specific gravity being 73, that of air being 1000. As commonly produced in chemical experiments from sulphuric acid acting on iron or zinc, it contains impurities which give it a disagreeable smell, but well-purified hydrogen is nearly free from any offensive odour.

A cubic foot of hydrogen weighs . .	37 grains
And, according to Dr. Henry's experiments, requires for its combustion .	300 grains of oxygen
The product of combustion being . .	337 grains of water.

This agrees as nearly as possible with the proportions derived from the chemical equivalent of water, which consists of one atom of hydrogen whose weight is 1, combined with one atom of oxygen whose weight is 8. Now 37 and 300 are

very nearly in the proportion of 1 to 8. Again, looking at the composition of water by measure, it appears that each volume of oxygen combines with two volumes of hydrogen to form water. Dr. Henry found that it required exactly one measure or volume of oxygen to consume two measures of hydrogen, and the accuracy of this determination is beautifully confirmed in the modern experiment of decomposing water by voltaic electricity. When this experiment has been continued a sufficient time, it will be found that the volume of hydrogen is a little more than double that of the oxygen. The excess is owing to the greater solubility of oxygen in water, otherwise the proportion of 2 to 1 would be obtained exactly.

Carburetted Hydrogen is a compound of carbon and hydrogen, in the proportion of one atom of the former to two of the latter, its chemical equivalent being CH_2. It is this compound which forms the inflammable fire-damp of coal-mines, and which proceeds abundantly from the decomposition of vegetable substances. This gas is colourless, nearly inodorous, and does not affect vegetable colours. By measure it consists of one volume of the vapour of carbon and two of hydrogen, which on combination are condensed into one volume. By weight the gas contains six parts of carbon and two of hydrogen; or 100 parts contain by weight,

Carbon	75
Hydrogen	25

This gas is very inflammable, and when mixed with a double proportion of oxygen it is readily explosive by means of a spark: the product remaining after explosion is carbonic acid, equal in volume to the carburetted hydrogen. Now, as carbonic acid contains its own volume of oxygen, it follows that the other volume of oxygen has combined with double its volume of hydrogen, this being the proportion required in order to render the mixture explosive. It follows from this experiment that a measure of carburetted hydrogen contains its own volume of carbon and twice its own volume of hydro-

gen, the three volumes when mixed forming only one volume. Its density is ·5594, the weight of 100 cubic inches being 17·41 grains.

Pure carburetted hydrogen gas has very little odour, and may be respired with safety. The unpleasant smell of common coal gas is due to the presence of impurities. In its natural forms of marsh gas and fire-damp, carburetted hydrogen is generally contaminated with nitrogen and with a small proportion of carbonic acid gas. Carburetted hydrogen burns with a flame far surpassing hydrogen both in density and illuminating power.

	grains.
A cubic foot of this gas weighs	300
Requires for its combustion 2 cubic feet of oxygen .	1200
	1500
The products are 1 cubic foot of carbonic acid .	817
And water	683
	1500

Carbonic Oxide, or the protoxide of carbon, consists of one atom of carbon and one of oxygen, its atomic weight being, carbon $6 +$ oxygen $8 = \mathrm{CO} = 14$. Hence, it consists by weight of 43 per cent. of carbon, and 57 per cent. of oxygen. Carbonic oxide is prepared in the laboratory by passing carbonic acid over red-hot charcoal or metallic iron, by which half its oxygen is removed, and it becomes converted into carbonic oxide. This change also explains the mode of its formation in the process of distilling coal for gas-making purposes. Carbonic oxide contains half its volume of oxygen, is a combustible gas, and burns with a beautiful blue flame, the product of its combustion being carbonic acid. This gas is extremely poisonous, even worse than carbonic acid, is colourless, and possesses very little odour. Its specific gravity is ·973, the weight of 100 cubic inches being 30·21 grains.

III. INJURIOUS PRODUCTS.

Carbonic Acid is another well-known oxide of carbon, containing two equivalents of oxygen to one of carbon. Its chemical composition is denoted by the expression CO_2; its atomic weight being 22, and proportions being 72·73 per cent. of oxygen, and 27·27 per cent. of carbon. This gas is readily procured in the laboratory by decomposing any of the earthy carbonates, as chalk or limestone, with a stronger acid, which forming a new combination with the earthy base sets free the carbonic acid of the carbonate. Carbonic acid gas is without colour, and though possessing an agreeable pungent taste and odour, cannot be breathed for a moment with impunity, as it rapidly produces the effect of suffocation and insensibility. This gas is familiar to us as the fatal choke-damp of mines, as the fixed air in champagne, bottled beer, soda water, &c., and as the heavy gas which floats over the large vats in breweries while the beer is undergoing the process of fermentation.

The specific gravity of this gas is 1·524, the weight of 100 cubic inches being 47·26 grains. Not only is this gas entirely uninflammable, but it instantly extinguishes flame even when diluted with three times its volume of air. The carbonic acid gas, owing to its great affinity for lime, is readily separated either by being exposed to the absorption of hydrate of lime, or that of lime diffused through water, as in the wet-lime purifiers. It is extremely injurious in gas intended for illuminating purposes, as it tends directly to destroy combustion. At the same time the great density of carbonic acid gas would give to any compound containing it a false appearance of value by exhibiting a high specific gravity, and hence its presence may reasonably be expected in gas with feeble illuminating power and considerable density.

	grains.
According to Dr. Henry, a cubic foot of carbonic oxide weighs	520
And requires for its combustion half a cubic foot of oxygen, weighing	300
The product being carbonic acid	820

Ammonia is produced during the distillation of coal by the union of hydrogen with the azote or nitrogen which is contained in coal, as in all other organic substances. In forming ammonia, one atom of nitrogen unites with 3 atoms of hydrogen, the chemical formula being $NH_3 = 17{\cdot}06$, and the proportions by weight being 82·41 per cent. of nitrogen, and 17·59 per cent. of hydrogen. The density of ammonia is ·589, the weight of 100 cubic inches being 18·26 grains. Two volumes of ammonia contain by measure three volumes of hydrogen and one of nitrogen, the whole being condensed to the extent of one-half. Ammonia is produced abundantly in nature from the decomposition of animal and vegetable substances: the gas is colourless and very pungent, acting strongly on the mucous membrane of the nose, eyes, and throat. The greater part of the ammonia is separated from gas by the condensing apparatus, the siphons of which admit the tar and the ammoniacal liquor to flow off into the same tank. The difference in the specific gravity of these two liquids produces a sufficient separation, the ammoniacal liquor floating on the surface of the tar. The ammoniacal liquor is the principal source from which ammonia is procured; and numerous patents have been taken out for improvements in the mode of treating this liquor, in order to effect the production of carbonates, muriates, and other salts of ammonia. The value of ammoniacal liquor as a manure for top-dressing grass lands and other applications has been much insisted on of late years. When diluted with four times its bulk of water and applied by means of cylinder carts or other contrivances for distributing liquid manure, the effect is said to be highly beneficial.

Although the ammoniacal liquor is at present the only source of ammonia in ordinary gas-works, there are other parts of the purifying process in which ammonia is separated, but not in sufficient quantities to be worth working. Where the breeze condenser is used, certain volatile oils together with ammonia are arrested; also where dry lime is used for purification, some volatile salts of ammonia are arrested, and certain carbonates

and sulphates of ammonia are decomposed and the ammonia set free. Some of this free ammonia is afterwards absorbed by passing the gas through a sheet of water in a machine called the Washer. An account of Mr. Croll's process for entirely separating ammonia from gas will be found further on.

Sulphuretted Hydrogen is one of the most injurious products contained in impure coal gas, and the greatest attention is now paid to the process of freeing the gas from this offensive compound. Sulphuretted hydrogen consists of one atom of sulphur combined with one atom of hydrogen, its atomic weight being $16{\cdot}09 + 1 = 17{\cdot}09$: by measure it contains one volume of hydrogen combined with $\frac{1}{6}$th of a volume of the vapour of sulphur, the two being condensed into one volume. The specific gravity of sulphuretted hydrogen is greater than that of common air, namely, 1·171, the weight of 100 cubic inches being 36·33 grains.

This offensive gas is most abundantly produced in the early part of the distillation, and towards the close of the process it disappears altogether. It increases the illuminating power of the gas, but this is far more than counterbalanced by the production of sulphurous gas from its combustion: this latter, besides being very injurious to all metallic surfaces, is extremely offensive and irritating to the breathing organs.

Sulphuretted hydrogen is a colourless gas, with an offensive taste and odour resembling that of putrid eggs. It is inflammable, burning with a blue flame, and emitting a suffocating smell. The effect of sulphuretted hydrogen in tarnishing metal is a certain indication of highly impure gas. This gas tarnishes silver plate as well as plated articles, and gives rise to suffocating vapours like those from the burning of a brimstone match. One of the most delicate tests for the presence of sulphuretted hydrogen is to expose paper moistened with a solution of acetate of lead to a jet of the gas; if any sulphuretted hydrogen be present, the surface of the paper is immediately blackened by the precipitation of metallic lead. This is one of the most severe tests of purity which can be applied to coal gas,

and although common at gas-works in this country, M. d'Hurcourt, the author of a recent work on the subject of gas, doubts if there is a single establishment in France where this test could be applied without detecting sulphuretted hydrogen. This gas possesses acid properties, its solution reddening litmus paper. Nearly all coal contains more or less sulphur, usually in combination with iron, in the form of sulphurets or iron pyrites. During the process of distillation these sulphurets are decomposed; the sulphur being driven off in vapour, and combining with hydrogen, the product is sulphuretted hydrogen. A considerable quantity of this compound is supposed to be separated by the condenser, and to be contained in the ammoniacal liquor; nevertheless a considerable quantity still remains in the gas, sufficient to render the purification by lime absolutely necessary. This purification is effected either by means of dry quick-lime merely sprinkled with water, or by means of wet lime in what are termed wet-lime purifiers. When dry lime is used it is necessary to have the lime greatly in excess, as it ceases to absorb sulphuretted hydrogen long before it becomes saturated. The absorbing action of the lime is said to be much increased by adding hydrous sulphate of soda: this has been proposed by Prof. Graham, (Phil. Mag., June, 1841,) who states that on the addition of the sulphate of soda the action continues till two equivalents of sulphuretted hydrogen have been absorbed by one equivalent of lime. The lime is entirely converted into gypsum or sulphate of lime, and the whole of the soda becomes bi-hydro-sulphuret of soda, which might easily be washed out of the lime: this bi-hydro-sulphuret may be readily again converted into soda by roasting it, and thus might be used over and over again to mix with the lime in the purifiers.

M. Penot has recommended the employment of sulphate of lead in solution for purification in towns where dye-works are situate, and where the sulphate of lead can be economically procured. The pipe delivering the gas should dip 8 or 10 inches into the solution, when a double sulphuret of lead will be precipitated, and the gas will be freed from sulphuretted

hydrogen, but will still require to be passed through lime to separate the carbonic acid and to decompose the carbonates of ammonia.

Sulphuret of Carbon.—There are two compounds of sulphur with carbon whose presence is suspected in coal gas, and which at the present moment are not successfully separated from it. The one is a gaseous compound consisting of one atom of sulphur combined with one of carbon. The other is a very volatile liquid composed of two atoms of sulphur and one of carbon. This is termed the bisulphuret of carbon,—a transparent colourless liquid, which boils at 110°, and emits vapour of considerable elasticity at common temperatures. The blue and livid appearance of some gas-lights may not improbably be due to the presence of the vapour of this bisulphuret. The problem of separating the sulphurets of carbon from coal gas is one of some difficulty; because, although the means of decomposing it are perfectly well known, yet these means are expensive, and it happens also that the same process would equally decompose the valuable olefiant gas and the carburetted hydrogen.

Cyanogen and Cyanates.—The property of nitrogen to unite with carbon and form cyanogen has been much studied of late years. Cyanogen is an inflammable gas, burning with a beautiful purple or peach-blossom coloured flame, generating carbonic acid and setting free nitrogen. It contains two equivalents of carbon and one of nitrogen, its atomic weight being 26. Cyanogen exists in considerable quantities in the ammoniacal liquor of gas-works, and the separation of the cyanates for the purpose of forming cyanide of potassium, prussiate of potash, ferrocyanide of iron (Prussian blue), and other compounds, is now becoming an object of importance. According to M. Jacquemyns, (Annales de Physique et de Chimie for 1843, p. 293,) the quantity of cyanogen and cyanates contained in a gallon of ammoniacal liquor is sufficient, when saturated with sulphuric acid, to form with a salt of iron 24 troy grains of Prussian blue.

CHAPTER III.

ON THE COALS USED FOR GAS-MAKING, AND EARLY EXPERIMENTS ON THE DISTILLATION OF COAL.

THE composition of coal is exceedingly various, and it would be quite impossible within the limits of this work to give anything like a minute description of the numerous varieties which are met with even in this country. Several of our single coal-fields frequently contain a complete suite of specimens, ranging from the most bituminous down to the most anthracitic or purely carbonaceous varieties. I shall only attempt, therefore, a very general classification of coals, and shall adopt the popular division proposed by Dr. Thomson in the 'Annals of Philosophy,' vol. xiv. He divides pit coal into three species; Brown Coal, Black Coal, and Glance Coal. The brown coal is a kind of lignite or imperfect coal found at Bovey Tracy in Devonshire, also in several parts of Ireland, France, Germany, Iceland, &c. It contains a large quantity of bitumen, producing volatile carburets when distilled: the texture is fibrous, with evident marks of vegetable origin: it burns with a bright flame, yielding a peculiar bituminous odour. It does not occur in sufficient quantity to render it of much importance in the manufacture of gas.

Glance coal or anthracite consists almost entirely of carbon, and contains only a very small proportion of volatile constituents. Although extremely valuable as a heat-giving coal, it is almost worthless in the manufacture of gas. It exists in great abundance in the western part of the South Wales coal-field, in Kilkenny, in Pennsylvania, and other parts of the world.

The varieties of black coal are for the most part valuable for the purposes of the gas manufacture. They are divided by Dr. Thomson into four sub-species,—namely, caking coal, splint coal, cherry coal, and cannel or parrot coal.

Caking coal, to which variety belong most of the Northumberland and Durham coals, is so named from the melting which takes place in a common fire-place, by reason of which the separate particles of coal become united together into one pasty mass or cake, which requires to be frequently broken up to allow currents of air to penetrate and promote its combustion. This coal is soft and easily broken, is very inflammable, and burns with a lively flame, giving out more heat in an open fire-place than most of the other kinds.

Splint coal, so called from its splintery fracture, is broken with more difficulty than the caking coal, and requires a higher temperature to light it. This is the best coal for making coke, and when used in furnaces gives out the greatest amount of heat. To this variety belongs the greater part of the coal used in South Wales for smelting the ores of iron and copper. It is probably the best coal in England for making coke for locomotive engines, and is the coal which appears from the experiments of Sir Henry de la Beche and Dr. Lyon Playfair to be the best adapted for steam boilers in the Navy.

Cherry coal is about the same hardness as caking coal and is easily broken; it is also easily lighted, and burns with a bright flame. It burns out quickly, not caking at all, but leaving fully 10 per cent. of ash, while the best Newcastle caking coal leaves only $1\frac{1}{2}$ per cent.

Cannel coal is harder than any of the other varieties, and is frequently cut into ornaments, which are not inferior in lustre to jet: it is very easily kindled, burns with a bright flame, and does not soil the bars of a grate. Cannel coal is extensively dug in Scotland, and is also procured from Lancashire, whence it is brought to the London market, both for use in gas-works and for domestic consumption, its cleanliness and cheerful crackling mode of burning being its chief recommendation. Cannel coal, according to Dr. Thomson, yields 11 per cent. of ashes.

Dr. Thomson gives the following analysis of the several varieties of black coal:

	Caking.	Splint.	Cherry.	Cannel.
Carbon . . .	75·28	75·0	74·45	64·62
Oxygen . . .	4·58	12·5	2·93	——
Hydrogen . .	4·18	6·25	12·4	21·56
Nitrogen . . .	15·96	6·25	10·22	13·72

The following Table shows the proportions volatilized by heat and the coke which remains:

	Caking.	Splint.	Cherry.	Cannel.
Volatile matter. .	774	647·3	522·5	400
Coke	226	352·7	477·5	600
	1000	1000·0	1000·0	1000

We are probably indebted to that eminent philosopher the late Dr. Henry, of Manchester, for the earliest scientific experiments on the distillation of coal, and also for the first experiments on the value of the gases produced. To this distinguished chemist we owe the announcement (Phil. Trans. of Royal Soc. for 1808) that the illuminating value of coal gas is in proportion to the quantity of oxygen required for its combustion, and that the specific gravity, although it does not bear an exact correspondence to the chemical properties of the gas, yet affords a measure of illuminating power sufficiently accurate for practical purposes.

Dr. Henry's experiments on distillation were chiefly made with the Wigan and other cannel coals; but it is remarkable that the quantity of gas which he obtained falls far short of that which is yielded in actual practice on the large scale. For instance, he finds that 340 cubic feet of gas are produced from 120 lbs. avoirdupois of Wigan cannel coal. This is only at the rate of 6347 feet per ton, a quantity far less than that now produced at all the London gas-works from the bituminous coals of Newcastle and the neighbourhood, which are inferior, as gas-producing coals, to the Wigan. The quantity produced at the present time from Newcastle coal certainly does not fall short of 9000 feet per ton, and some recent authorities have estimated the quantity at a much higher rate.

The gas spoken of by Dr. Henry is said by him to have an illuminating power equal to one mould candle of six to the pound when a jet of gas consuming half a cubic foot per hour is employed.

In Dr. Henry's experiments on coals he found that when a low red heat was used, small quantities of sulphuretted hydrogen and carbonic acid gases came over at first, in mixture with the other gases, but in a gradually diminishing proportion, till at length in the last products they were not discoverable at all. In the same way the largest proportion of olefiant gas was yielded at first, the quantity gradually diminishing, as determined by the gas requiring less and less oxygen for its saturation. The gas from the Wigan cannel coal was found to possess the highest illuminating power, that from the anthracite of South Wales the lowest.

Dr. Henry made the following experiments by collecting the gas at intervals in a bladder furnished with a stop-cock, which was fixed into an opening in the pipe between the retort and the hydraulic main. This he terms impure gas. The purified gas was freed from carbonic acid and sulphuretted hydrogen by a solution of pure potash applied in very small quantity relatively to the volume of the gas, and with the least agitation adequate to the effect.

Table showing the Quality of Gas from 1120 lbs. *of Cannel Coal at different periods of distillation.*

Hours from commencement.	100 measures of Impure Gas contain		100 measures of Purified Gas consist of			100 measures of Purified Gas	
	Sulph. hydr.	Carb. ac.	Olef.	Other Inf. Gases.	Nitrogen.	consume Oxygen.	give Carb. ac.
½ an hour . .	0½	5½	16	64	20	180	94
1 hour . . .	3	3½	18	77¼	4¾	210	112
3 hours . . .	2½	2½	15	80	5	200	108
5 " . . .	2½	2½	13	72	15	176	94
7 " . . .	2	2½	9	76	15	170	83
9 " . . .	0½	2½	8	77	15	150	73
10½ " . . .	0	2	6	74	20	120	54
12 " . . .	0	½	4	76	20	82	36

Excluding from the calculation the nitrogen gas, with various proportions of which the products were contaminated, the following Table shows the quantity of oxygen gas consumed and of carbonic acid gas produced by the really combustible part of the gas.

100 measures of	Take oxygen.	Give carb. ac.
½ hour gas . . .	225	118
1 „ „ . . .	220	117
3 hours „ . . .	210	114
5 „ „ . . .	206	108
7 „ „ . . .	200	98
9 „ „ . . .	176	85
10½ „ „ . . .	150	70
12 „ „ . . .	103	45

Table showing the Quality of the Gas from 1120 lbs. *of common Coal at Clifton Gas-Works, Manchester, at different periods of the distillation.*

Hours from commencement.	100 measures of Impure Gas contain		100 measures of Purified Gas contain			100 measures of Purified Gas	
	Sulph. hydr.	Carb. ac.	Olef.	Other Inf. Gases.	Nitrogen.	consume Oxygen.	give Carb. ac.
1 hour Gas .	3	3	10	90	0	164	91
3 hours „ .	2	2	9	91	0	168	93
5 „ „ .	3	2	6	94	0	132	70
7 „ „ .	1	3	5	80	15	120	64
9 „ „ .	1	2½	2	89	9	112	60
11 „ „ .	1	1	0	85	15	90	43

Comparative Table of the Qualities of Gases from Wigan and from common Coal at equal times from the commencement of the distillation.

	Oxygen consumed by 100 measures of Cannel gas.	Oxygen consumed by 100 measures of Clifton gas.
1 hour Gas . . .	220	164
3 hours „ . . .	210	168
5 „ „ . . .	206	132
7 „ „ . . .	200	140
9 „ „ . . .	176	123
11 „ „ . . .	150	106

It appears from the above that gas from cannel coal has an illuminating power one-third greater than that from common coal.

Dr. Henry states the quantity of gas procured from cannel coal at 7000 cubic feet per ton, and from common coal at 6000 cubic feet per ton.

One distillation of cannel coal mixed in the gas-holder required 155 measures of oxygen gas for the combustion of 100 measures of the gas, and gave 88 measures of carbonic acid; but as this gas was contaminated with 15 measures of nitrogen in every 100, the oxygen required for saturating 100 measures of the really combustible part may be stated at 195, and the carbonic acid at 110.

Dr. Henry is of opinion that on the large scale, as in the actual working operations of gas-making establishments, the quantity of olefiant gas is greater than that yielded in small experiments. He attributes this to the greater regularity and uniformity of the temperature.

Nitrogen is not evolved during the first hours of distillation, because in the first part of the process it combines with hydrogen and forms ammonia; but when the retort and its contents are fully heated, and the heat well kept up, ammonia is either not formed, or, if formed, is again decomposed into its elements hydrogen and nitrogen, both of which may be traced in the products of more advanced stages of the distillation.

There are two things which should be especially avoided in the manufacture of gas,—namely, too low a heat, and a too long continuation of the distillatory process. The effect of too low a heat is a great diminution of the gaseous products, the chief result of the distillation being the production of tar. The effect of continuing the distillation too long is, that gases of very feeble illuminating power are evolved together with nitrogen, which when once mingled with the combustible gas cannot be removed by any known method, and must seriously impair its illuminating power.

I shall reserve for a future chapter some experiments on the comparative quantity of gas produced by different kinds of coal.

CHAPTER IV.

ON THE MANUFACTURE OF COAL GAS.

BEFORE entering on a description of the apparatus used in the manufacture of coal gas, it may be advisable to take a brief review of the various processes through which the gas passes, from the time of its first production till its arrival in the gas-holders to be stored for use.

These processes may be conveniently divided into carbonizing and purifying,—the first comprising the distillation of the coal and the collection of the gas in the hydraulic main, —the second comprising all the changes effected in the gas between the hydraulic main and the gas-holders.

1. *Carbonization of the Coal.*

The first process is that of heating the coal in retorts of iron or earthenware, or in brick ovens, applying sufficient heat to drive off the gas; and when this is efficiently performed, the product left in the retort is simply coke, chiefly consisting of carbon, and containing neither bitumen, tar, nor any other volatile matter, and incapable of yielding any more gas. The gas driven off from the coal passes up a stand-pipe from each retort, and descends down a dip-pipe into the hydraulic main, which is usually a tube about half-filled with water or tar, extending across the ends of the retorts. The dip-pipes each pass below the surface of the tar, through which the gas bubbles up into the space above, but cannot again return into any of the retorts; so that the gas once arrived in the hydraulic main is fairly secured, and ready to be dealt with for the purpose of purification.

2. *The Purifying Process.*

The gas when it leaves the retorts contains a considerable quantity of tar, besides ammonia, sulphuretted hydrogen, and carbonic acid, all of which require to be separated before it becomes proper to dispense for illuminating purposes.

The hydraulic main receives a considerable proportion of the tar and ammonia, so that in time the water originally placed in the hydraulic main becomes displaced by the tar and ammoniacal liquor deposited from the gas. Other proceedings however are necessary to separate portions of tar and ammonia which remain in the gas after leaving the hydraulic main.

As the order in which these processes are followed varies at different works, they can scarcely be described in a consecutive manner. In attempting to arrange them, however, I shall point out where the succession varies.

a. The process of washing the gas is adopted for the purpose of separating ammonia, and consists of passing the gas through a simple sheet of water 6 or 8 inches in depth.

b. The scrubber or breeze condenser is used for the same purpose, and is frequently adopted as a substitute for process *a.* It consists of passing the gas through layers of cinders or breeze, and acts mechanically in separating ammonia.

c. The air or water condenser is used for the purpose of cooling the gas, and thereby causing tar and ammoniacal liquor held in suspension to separate from it before subjecting the gas to the purification by lime.

d. The next process is that of passing the gas through either wet-lime or dry-lime purifiers, for the purpose of separating sulphuretted hydrogen and carbonic acid.

Of the four processes here described, the two last—namely, *c* and *d*—are indispensable in all gas-works. The two first, *a* and *b*, are sometimes omitted; usually only one of them is used; that is, where process *a* is adopted before the air or water condenser, the scrubber is altogether omitted. In some works, the gas on leaving the hydraulic main is passed through

process *b*, and then the gas is not washed by process *a* till after the lime purification, and in many works process *a* is altogether omitted.

Process *c* is highly important, and much of the value of gas depends on the efficiency with which it is performed. Latterly an intermediate contrivance has been used for separating ammonia between the condenser and the lime purifiers by passing the gas through a metallic salt. This is Mr. Croll's patent process, now used at the Central Gas Consumers' Works, and some others.

Where wet lime is used for purification it is usual to have an exhauster placed generally between the hydraulic main and the condenser, the object of which is to relieve the gas in the retorts from the pressure occasioned by the head of water which it has to pass through, where purification by wet lime is resorted to. Almost the same necessity for an exhauster exists where the lime is passed through a wash vessel.

Such is a brief summary of the various processes through which the gas passes before it reaches the gas-holder; a summary purposely made brief in this place, because each subject will be more fully treated on when we come to consider the apparatus used in each department.

CHAPTER V.

ON THE RETORTS USED IN GAS-MAKING.

The iron or earthenware vessels in which coal is distilled for the purpose of driving off its gas are called retorts,—a name borrowed from the language of chemistry, in which a retort signifies any vessel either of glass, earthenware, or metal, in which distillation or decomposition is effected by the application of heat. The French, in their word *cornue*, have obviously adopted the name of a chemical vessel in the same manner to designate the retorts used in the distillation of coal gas.

The earliest experiments on the form of retorts appear to have been made by Mr. Murdoch, who in 1798 erected a gas apparatus at the works of Messrs. Boulton and Watt, at Soho. The retort used there was a circular tube whose diameter was equal to a third of its length. The retort was placed vertically over the fire-grate, and a horizontal pipe from the upper end conveyed away the gas. The open end of this retort was of course uppermost. The form of these vertical retorts was afterwards varied, as it was found very inconvenient to extract the coke from a retort which opened only at the top. The next form was somewhat in the shape of a wine decanter, that is, of larger diameter at the base than at the top: the fire acted on the bottom and sides of this retort. In the side close to the bottom was an opening for extracting the coke, and a vertical pipe went off near the top for carrying away the gas. This form did not answer, owing to the mass of coal lying too much in a heap, and not presenting a sufficient bottom surface, so that an outer coat of carbon was formed, which prevented the heat from penetrating quickly to the interior.

The next contrivance was that of a cylindrical retort placed

diagonally in the furnace. From this the coke could be readily extracted at the lower end, but the heat did not act so effectually as in the next form, which was that of a cylindrical retort placed horizontally. The shape of this last was varied, being sometimes cylindrical in section, sometimes oval or ear-shaped, but the horizontal position and mode of setting were retained.

IRON RETORTS.

The various kinds of iron retorts in use at the present time are chiefly set horizontally, and are of uniform section throughout, except towards the open end, where they are either contracted slightly on plan and furnished with a flange to which the mouth-piece is bolted, or the open end is formed into a socket to receive the end of the mouth-piece, and in some retorts the section is quite uniform without any contraction. The mouth-piece is usually about 10 inches long, with a socket cast on it to receive the end of the stand-pipe which conveys the gas to the hydraulic main. The retort, therefore, has no opening cast in it for this purpose, but is simply a tube or other figure open at one end.

The iron retorts used by Mr. Croll, the Engineer of the Central Gas Consumers' Company, and for many other works, vary materially from those with mouth-pieces. His retorts are 19½ feet long, charged with coal at both ends, so that there is a lid at each end, but no separate mouth-piece. Close to one end of the retort a 5-inch hole is cast to receive a flange-socket for fixing the ascension pipe leading to the hydraulic main. These retorts will be more particularly described at a future page.

Iron retorts may be divided into D-shaped or flat-bottomed retorts,—rectangular, elliptical, and circular retorts. The D-shaped are made of two principal sizes; the small London D about 12½ inches wide by 12½ inches deep in the clear, and varying in length from 6 to 9 feet, and the York D, which is usually made wider, generally 20 inches to 2 feet or even 30 inches

wide, by a height varying from 9 inches to 14 inches, the length being variable within about the same limits as the small D. The rectangular retorts are usually about 18 inches wide by 12 inches deep, with the corners rounded off, and sometimes with the roof arched. Elliptical retorts are of various dimensions, the longer axis varying from 18 to 24 inches, and the shorter from 11 to 18 inches. Besides the regularly shaped elliptical retorts there is a form termed ear-shaped, a section of which is shown in fig. 1. The general size of this form, which has not been much used exeept by Mr. Clegg, who introduced and used it in Liverpool, is about 2 feet in breadth by 10 inches in height. The mouth-piece of this retort is not ear-shaped, but elliptical.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

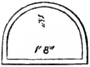


Fig. 5.

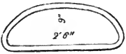


Fig. 6.

Figures 2 to 5, drawn on a scale of $\frac{1}{30}$th of the full size, show sections of the other retorts mentioned above, fig. 2 being the smallest sized London D, fig. 3 an intermediate sized D, and fig. 4 the York D. Fig. 5 is the section of a flat-bottomed semi-elliptical retort used in some of the Paris gas-works, and fig. 6 is the rectangular retort used in Philadelphia. The dimensions given above for circular and elliptical retorts sufficiently explain their shape without the aid of sections.

The usual charge for iron retorts such as have been described is from 120 lbs. to 200 lbs. of coal, according to their

size. When charged every four hours they are said to be worked with four-hour charges. Various durations have been tried, as four, six, and eight hours, but six-hour charges are now generally adopted, so that the carbonizing power of a retort in twenty-four hours is usually four times the charge; as for instance, a retort charged every six hours with $1\frac{1}{2}$ cwt. of coals is said to carbonize 6 cwt. in twenty-four hours.

Circular retorts are made from 14 inches to 21 inches in diameter, their lengths ranging as described for the D retorts.

In small country gas-works, where the retorts are set singly, one or other of these forms is used, but it is not unusual in large works where three, five, seven, or nine retorts are set in one oven, to see several different forms of retorts in the same bench. Frequently the lower retorts in the bench are D-shaped, and the upper ones circular or elliptical, the variations in shape and sectional area giving facilities for filling up to the haunches of the arch which is always built over the retorts when set in benches.

The closed end of these iron retorts is generally square, but it is thought to be an improvement to have ends curved, as in the retorts of the Philadelphia gas-works, fig. 24. This shape is said to prevent the burning out of the back, so much complained of in the usual form. When retorts are charged with a scoop, as now generally practised, a very small quantity of coal is lodged at the further end: at the same time the heat is much fiercest at this end, and consequently the back of the retort is very soon burnt out. To remedy this evil, some intelligent managers in using square-backed retorts direct the men to throw in several shovels of coal quite up to the end of the retort, and then to thrust the scoop well forward, and deliver its contents as far back as possible. It is said this method of heaping the charge at the further end prevents in a great measure the backs from burning out. In using retorts with circular ends this precaution is unnecessary, as the fire does not act with so much violence on the curved part, and the retort will wear out regularly when charged in the ordinary way.

Fig. 7.

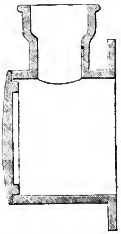
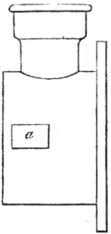


Fig. 8.



Figs. 7 to 11, drawn to a scale of $\frac{1}{12}$th or one inch to a foot, show details of a flanged mouth-piece for a small London D retort. Fig. 7 is a longitudinal section of mouth-piece, showing the socket cast on it to receive the stand-pipe, and also the lid affixed to the mouth. Fig. 8 is a corresponding elevation, showing the ear box, *a*, cast on each side of the retort to receive the ears, which are usually 14 inches long.

Fig. 9.

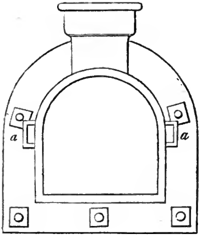


Fig. 10.

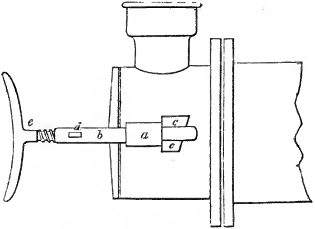
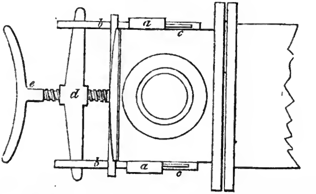


Fig. 9 is a front elevation showing the mouth-piece attached to the retort, but without the lid of the mouth-piece. Fig. 10 is a side elevation, and fig. 11 is a plan of the mouth-piece attached to the retort, showing also the lid and the mode of

Fig. 11.



securing it to the mouth-piece. *b b* are the ears passing through the ear-boxes, *a a*, and secured by wedges, *c c*. *d* is the cross-bar through which passes the screw, *e*, which presses on the lid and firmly secures it to the mouth-piece. The part of the lid which presses against the edge of the mouth-piece is luted round with a composition of lime mortar

and fire-clay, which is pressed out round the edges and makes a perfectly gas-tight joint.

Fig. 12.

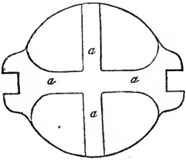
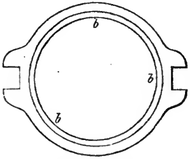


Fig. 13.



Figs. 12 to 17, drawn on a scale of one inch to a foot, show various forms of lid. Figs. 12 and 13 show the outer and inner surface of a lid for a circular mouth-piece of 15 inches inside diameter. Figs. 14 and 15 show the same surfaces of

Fig. 14.

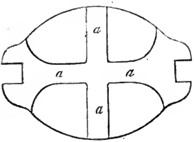
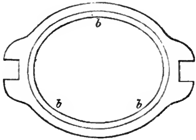


Fig. 15.



a lid for an oval mouth-piece 16 × 13 inches in the clear, and figs. 16 and 17 show a lid for a small D mouth-piece $12\frac{1}{2}$ inches × $12\frac{1}{2}$. The thickness of the lid in all these cases is $\frac{5}{8}$ths of an inch, but the ribs marked *a* on the front elevation project $\frac{1}{8}$th of an inch, so that the thickness at the ears and at the centre where the screw presses is $\frac{3}{4}$ths of an inch. The inner rim shown at *b* on the inside elevation projects $\frac{3}{4}$ths of an inch inside the mouth-piece, and leaves $\frac{1}{4}$th of an inch

Fig. 16.

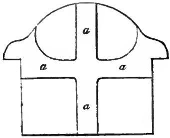
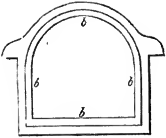


Fig. 17.



space all round between itself and the inner surface of the mouth-piece.

It should be explained that when the lid is lifted off, the ears *b b*, figs. 10 and 11, are not removed, but are kept fixed in the ear-boxes, as shown in the drawings. In order to take out these ears, it is of course necessary to loosen the wedges, *c c*, figs. 10 and 11, when the ears can be immediately withdrawn; but this is never done in the process of removing or fixing on the lid.

There are various modifications of the parts connected with the lid, which may be briefly noticed. Sometimes the ear-boxes are so cast as to have no top, in which case they form a simple rectangular notch cast on each side of the mouth-piece. The ears, again, are not always perforated with the holes to receive the ends of the cross-bar, but have sometimes a simple notch in which the ear-bar rests. Both these modifications will be observed in the arrangement of the mouth-pieces in the Philadelphia Works, figs. 23 and 24.

There is yet another method of fastening the lid, in which the screw is altogether dispensed with, as shown in figs. 18 and 19. Here the ears form supports for an axis, *a*, which carries a lever formed at one extremity into a sort of excentric or cam, and carrying at the other end a globe of solid cast iron about 4 inches diameter. When the globular end of this lever is depressed, the cam presses with considerable force upon the back of the lid, and holds it as effectually in its place as

Fig. 18.

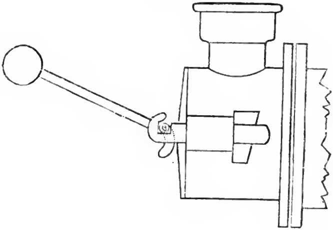
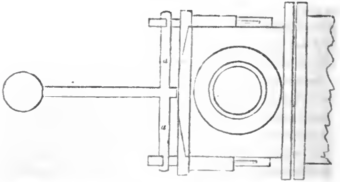


Fig. 19.



the screw: in addition to which, if required, it is easy to increase the pressure by hanging on the globular end of the lever an iron ring or other weight.

The usual iron cement employed where heat is present should be used for the joint between the mouth-piece and the retort. The flanges should not touch each other, but should be kept about $\frac{3}{8}$ths of an inch apart by iron wedges, and the cement well filled in between them with a caulking chisel.

The cement is prevented from passing through and falling into the mouth-piece by having a strip of hoop-iron placed inside, which is removed when the joint is finished. A chemical union takes place between the iron surfaces and the ingredients of the cement, which renders it difficult to define the line of separation, and produces a joint perfectly impervious even to the most volatile and diffusible gas.

The recipes for making iron cement vary considerably. Mr. Peckston says 1 ℔. of iron borings or turnings are to be pounded in a mortar into the state of fine dust or powder; these are to be mixed with 2 oz. of sal ammoniac in powder and 1 oz. of flower of sulphur; the whole to be thoroughly incorporated by being pounded in a mortar. When required for use, take one part by measure of the above compound and mix it with 20 parts of pounded iron borings, adding water to bring the mixture to the consistence of ordinary mortar. This cement may be applied in making all sorts of flange joints, as in securing the mouth-pieces to the retorts, the dip-pipes to the hydraulic main, &c.

Mr. Clegg's recipe is somewhat different: he uses

Iron borings or turnings	32 oz.
Sal ammoniac	1 ,,
Flower of sulphur	1 ,,

To be well mixed together, and kept dry for use. When required, water to be added to bring the mixture to a proper consistency.

The French employ for the same purpose a cement called the mastic d'Aquin, which is thus prepared:

98 parts of clean iron turnings pounded and passed through a sieve.

1 part of flower of sulphur.

1 part of sal ammoniac dissolved in sufficient boiling water to bring the whole mass to the consistency of ordinary mortar.

This cement is not prepared till required for use, and should be used as soon as possible.

The iron retorts which have been described are usually $1\frac{1}{4}$ inch thick, sometimes diminished towards the open end to $\frac{3}{4}$ths of an inch. The metal of the mouth-piece is usually from $\frac{5}{8}$ths to $\frac{3}{4}$ths of an inch in thickness.

The following Specification of the iron retorts $19\frac{1}{2}$ feet long, recently erected at the Central Gas Consumers' Works, is so clear as to render every part of them intelligible without the aid of drawings.

Iron Retorts.—To be of the D form, 98 in number, each 19 feet 6 inches long, $12\frac{1}{2} \times 12\frac{1}{2}$ inches across inside, and $1\frac{1}{4}$ inch thick; cast on end, and made of equal quantities of Nos. 1 and 2 iron re-melted from the cupola.

The whole of the retorts to be of uniform thickness and bore throughout, save the last 2 feet at each end, which shall diminish in thickness from $1\frac{1}{4}$ inch to $\frac{3}{4}$ths of an inch in thickness at the front; the ends to be chipped perfectly flat.

Ear-boxes to be cast on at each end, similar to those on an ordinary mouth-piece; at one end the ear-box to be 6 inches long, and at this end a 5-inch hole in the top of the retort, its centre being 5 inches from the end, with four bolt-holes to admit $\frac{5}{8}$th bolts to fix on the saddle-pipe; at the other end the ear-boxes to be only 3 inches long, and at this end there will not be any hole for ascension-pipe.

Lids.—To be of the usual kind, two to each retort, $\frac{5}{8}$ths of an inch in thickness, excepting at the ears, where they shall be $\frac{3}{4}$ths of an inch thick; the ears to be $1\frac{1}{2}$ inch deep where they rest on the ears of the mouth, and 2 inches long; the lid not to project beyond the width of the retort. A rim, standing $\frac{3}{4}$ths of an inch forward on the inside, measuring 12 inches over, thus leaving $\frac{1}{4}$th of an inch of margin all round on the inside: a pattern will be provided.

Cross-bars and Ears.—A set to each retort; the ears to be of good malleable iron, not less than 14 inches long, 2 inches broad, and $\frac{5}{8}$ths inch thick, rounded on the outside end, having a slit through their thickness 4 inches long by $\frac{5}{8}$ths broad, terminating at 2 inches from the front. A slit to be

cut through the breadth of the ear an inch from the back end, $\frac{1}{4}$th of an inch wide and 4 inches long, with a thin flat wedge of iron to suit, as in the ordinary manner.

The cross-bar screws to be made of the best and toughest wrought iron; the cross-bar to be 18 inches long, 2 inches broad at each end by $\frac{1}{2}$ inch thick, and $2\frac{1}{2}$ inches broad at the centre, where it will be 2 inches over, with a 1-inch screwed hole through its centre, as in the usual manner.

The cross-head to be 14 inches long of $\frac{3}{4}$ths round rod, save the screwed part, which shall be 12 inches long, 8 inches of which shall be 1-inch round rod, with a strong square thread cut in it, as in the usual manner.

Saddle-Pipes.—To be 98 in number, 10 inches high, 5 inches diameter, common socket at top, concave flange at bottom $2\frac{1}{2}$ inches broad clear of the pipe; the concavity of the flange to fit the convexity of the top of the retort.

Four $\frac{3}{4}$-inch screwed bolts to fasten each to the retort.

BRUNTON'S PATENT RETORT.

The retort used by Mr. Brunton at the West Bromwich Gas-Works is an extensive innovation on all other forms. Instead of being uniform in section throughout, the figure is that of a frustum of a cone, the diameter at the smaller end being 15 inches, and at the larger end 21 inches. The length of the retort is 4 feet 6 inches, and as it is set with the upper surface horizontal, the lower surface has a slope of 6 inches to facilitate the discharge of the coke, which is expelled not by being raked out as from the ordinary retorts, but by a peculiar contrivance, which will be presently noticed. The retort as it comes from the foundry is open at both sides, and provided with flanges for attaching a mouth-piece at each end. The mouth-piece at the small end is permanently attached with iron cement, bolts and nuts; the mouth-piece at the other end is also permanently attached, but is provided with a lid secured by a screw like the lid of the ordinary mouth-piece, and which

can be taken off, when required, to examine the interior of the retort. The mouth-piece at the smaller end is provided with a hopper capable of holding from 20 to 28 lbs. of coal, the admission of which to the retort is effected by withdrawing a slide, which is closed immediately after the delivery of the charge. The mouth-piece is also furnished with a horizontal projection, in which works a piston with its rod passing through a stuffing-box in the closed end of the mouth-piece.

The retort is charged every hour or oftener with the contents of the hopper, and the piston is used for pushing forward the coal and expelling the coke in order to make room for another charge. The piston is worked by a double-threaded screw, which is turned round by means of a handle at the end. The coke which is driven forward to the wider end of the retort falls through a close shoot, the end of which is sealed by dipping into a cistern of water which receives the coke. A rake or shovel, or an endless chain with buckets, is afterwards used for taking the coke from the cistern. Mr. Brunton employed at West Bromwich a variety of Staffordshire coal, which swells considerably during the process of carbonization, and hence his reason for using a retort so much wider at one end than the other, in order that no obstruction might take place in the passage of the coke. The retort has been described as the frustum of a cone, and therefore having a circle for its section; but the patentee does not confine himself to this form, and in fact rather prefers a D shape, the section at every point being a D, but increasing towards the wider end in about the same proportion as the circular one of which the dimensions have been given.

Mr. Brunton, after working these retorts for some time, claims considerable superiority over the usual forms. He says that they effect a great saving of labour, time, and tools, as neither rakes, scoops, nor iron barrows are required. Besides this, the retort being open at each end, and the charge of fuel having to pass directly through it, there is no deposit of carbon, which is an evil of great magnitude in the old retorts and

hastens their destruction in a very remarkable manner. The old retorts seldom last longer than 10 or 12 months; but Mr. Brunton states, that his retorts at the end of 12 months have been taken down and found quite free from incrustation. To the peculiar arrangement of his retort, in which the fuel is introduced at one end, and the coke and gas pass off at the other end, Mr. Brunton attributes great chemical advantages, as all the gases and vapours from the newly introduced coal must pass over the red-hot coke and undergo a more perfect decomposition than that which is possible on the old plan.

It is the opinion of many chemists and others who have attended to the distillation of coal, that in the ordinary retorts a great deal of the vapour and solid carbon in a fine state of division, which pass up through the stand-pipes and form the tar and ammoniacal liquor, would, if subjected to a greater heat, be decomposed and form carburetted hydrogen, of which they contain both the elements. It must be obvious, if Mr. Brunton's retorts do effect this decomposition, the produce of gas must be considerably increased,—a fact which derives confirmation from his statement that the tar, naphtha, and ammoniacal liquor, condensed from gas made in his retorts, is 50 per cent. less than in ordinary retorts. This being the case, as proved in the working of fifty retorts at the West Bromwich Works, it appears certain that this diminution of the residuary products must have been accompanied by a proportionate increase in the quantity of gas.

These retorts were used exclusively at the West Bromwich Works during the engineership of Mr. Brunton. At his retirement, however, some years ago, the Directors became dissatisfied with them,—finding they were more troublesome to manage and required greater attention than the ordinary kind; they were therefore taken down as they became worn out, and replaced by others, so that none of them are now in use. Mr. Brunton still retains the highest opinion of them, but, being now advanced in years, is unable to give the attention which the subject requires.

LOWE'S RECIPROCATING RETORTS.

Mr. George Lowe, an eminent Gas Engineer, has patented a kind of retort and mode of working it, which secures the object of decomposing the bituminous vapours which first pass off from the distillation of the coal. Mr. Lowe's retort is open at both ends,—is twice the length of those commonly used,—is charged at each end,—and he prefers them made of wrought iron, the section being that of the small or London D. These retorts have a mouth-piece at both ends,—each mouth-piece being fitted with stand-pipes, from which bridge-pipes and dip-pipes communicate with a hydraulic main which extends transversely across the line of retorts in the usual manner.

Each dip-pipe passes into the tar of the hydraulic main, which seals it in the usual manner, but the dip-pipe from one end dips into a greater depth than at the other, so as to form a more complete seal. Hence, without some other contrivance, the gas would always pass off at that end of the retort which is sealed to the smallest depth, the resistance at that end being less than at the other.

In order to give the power of regulating the escape so as to make it take place at either end, the shortest dip-pipe, or that with the smallest seal, is furnished with a cup-valve, which, when acted on by a lever, immediately closes the end of the dip-pipe so that the gas shall have no way of escape except at the other end of the rctort, where the dip-pipe is longest.

The retort being heated to a bright red heat is first charged at the end of the long dip-pipe by a scoop, which reaches only half the length of the retort. Both mouth-pieces are then closed, and the gas passes off into both the stand-pipes, but the resistance being least at the further end, will of course only escape at that end after traversing the red-hot part of the retort which is designed to decompose the vapours of tar and ammonia first passing off, and thus to increase the volume of gas. When the charge has been half-worked off, say in four

hours, the lid is to be taken off the mouth-piece at the empty end of the retort, a charge of coal introduced, and the mouth-piece closed as usual. The cup-valve is at the same time to be raised in order to close the mouth of the dip-pipe at this end, so that the gas now evolved will mix with that passing off from the half-distilled coals of the other end, and escape into the hydraulic main from the long dip-pipe. Here again the decomposition of the vapours of tar and ammonia is said to be effected in the same manner as before. When another interval of four hours has elapsed, (that is, an interval of half a charge, supposing the retorts to be working with eight-hour charges,) the lid of the mouth-piece with the long dip-pipe is opened, and the residue or coke remaining from the first charge is withdrawn in the usual manner, and a new charge of coal introduced. The cup-valve of the shut dip-pipe is then opened, and suffered to remain open for four hours, and so this series of operations is carried on during the whole time of working.

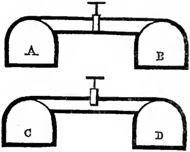
The principle of Mr. Lowe's patent has been for some time practised at the Pancras Station of the Imperial Gas Company, with some modifications, however, which I proceed to notice. The retorts are furnished with a mouth-piece at each end, but only one hydraulic main is employed. The retorts are set four in a bench, two being placed horizontally side by side, and two others placed above them. The mouth-pieces at the further end of each pair of retorts are connected by a pipe fixed to the mouth-pieces. These pipes are provided with valves so as to open or close the communication between the retorts as required.

In place of any difference in the sealing of the dip-pipes, a valve is provided for each dip-pipe, so that the gas may be cut off from any one of the retorts, and made to pass into the hydraulic main through the dip-pipe of the other. The retorts are charged at each end, as described in the abstract I have given of Mr. Lowe's method; and it is evident that by means of the valves in the connecting pipes and the dip-pipes, the same effect can be produced as in Mr. Lowe's original con-

trivance of two hydraulic mains, his two kinds of seals, and cup-valve.

Thus, let A B C D in fig. 20 represent the four retorts with their connecting pipes. The retorts being all brought up to the requisite heat, the lids of A and C are taken off, and the coal introduced at each end, when the lids are replaced. The slides in both the connecting pipes are then opened, and the slides in the dip-pipes belonging to A and C are both closed. The gas then passes from A and C into the empty retorts B and D, and escapes into the hydraulic main through the dip-pipes attached to those retorts. This continues during half the interval of the charge, namely, three or four hours, according as the time of charging is six or eight hours. The slides in the connecting pipes are then opened, the slides in the dip-pipes belonging to C and D are closed, and those of A and C opened. The other two retorts B and D are now charged, the valves in the connecting pipes again opened, and the gas first produced allowed to pass into A and C, there mingling with the last portion of gas produced in them and receiving the benefit of their great heat. At the end of the next period of three or four hours, as the case may be, the coke is withdrawn from A and C, when they are immediately charged a second time, and so the process goes on during the whole time of working. This method is said to be more complicated and to require more attention than Mr. Lowe's original plan. The gas produced on this principle by the Imperial Gas Company is said to be considerable in quantity, but only of average quality, owing to the deposit of some of its carbon in passing through the second red-hot retort. In Mr. Lowe's plan this evil is not so much experienced, as the red-hot surface to be passed over is not so

Fig. 20.



great. Mr. Clegg suggests that the number of retorts in a bench should be increased, and that the gas first produced should not be allowed to pass over the heated surface more than an hour, instead of three or four hours as now practised.

REVOLVING WEB RETORT.

This kind of retort differs very widely from the ordinary form, and not less so in the mode of charging it with coal. In those which have hitherto been examined the coal has been added to the retort in large quantities, varying from 120 lbs. to 200 lbs. for single retorts, and double this quantity for retorts which are charged at both ends. The disadvantages of this method are very obvious, and will be further alluded to. It may be sufficient at present to draw attention to the fact, that with the ordinary form of retorts, when heavy charging and low heats are employed, the quantity of tar is enormously increased, and taking an extreme case, it would be quite possible to carbonize the coal in such a manner as to produce no gas at all, nothing in fact but tar and bituminous vapours which would condense into tar. This may with reference to gas-making be termed the extreme of bad management, and the very worst form of conducting the process. The other extreme,—namely, that in which the largest quantity of gas is made and the least quantity of tar,—is effected, as may be expected, by an entirely opposite system of working, that is, by employing a much greater heat, and by exposing the coal in a very thin stratum to be acted upon and converted into gas almost instantaneously. This object is effected in a very remarkable manner by the mode of working now under consideration, as it converts into illuminating gas nearly all that bituminous vapour which condenses into tar in the ordinary process.

The retort employed for this purpose is flat-bottomed and about 26 inches wide, with an arched top, giving a depth of about 7 inches in the middle and 3 inches at the sides. An

endless chain or web is constantly passing through the retort, motion being given to the chain by the revolution of two six-sided drums, one of which is placed at each end of the retort. The revolving web consists of plates of iron 2 feet long by 14 inches wide, connected together by links of $\frac{5}{8}$-inch round iron. The coal, broken into very small pieces, is admitted to the web through a hopper, which has a feeder fixed in the lower part or neck of the hopper. The feeder is merely a casting 2 feet wide, with six radial projections; its diameter, which is usually about 9 inches, being so regulated that each of the six partitions of the feeder delivers enough coal to cover one plate of the web to the depth of $\frac{3}{8}$ths of an inch, or about 126 cubic inches of coal. The hopper is made large enough to contain a twenty-four hours' charge, which must be thrown in at once, and as the hopper is open to the retort, the top must be secured either by a luted cover or by a water-joint: the coal must either be ground or otherwise so reduced in size that no piece shall exceed the size of a common bean. The feeders are fixed on a revolving shaft worked by a strap at one end of the retort-house, the shaft extending the whole length, and having a feeder fixed on it for each retort.

The revolving drums, of which there are two for each retort, are also fixed on shafts extending the whole length of the retort-house. The periphery of the drum is equal to the length of the retort (7 feet), so that in one revolution, which takes places in fifteen minutes, the coal will have passed through the retort and become converted into gas. The section of the carbonizing part of the retort has been already described; the lower part, separated from the other by a mass of solid brick-work, has a rectangular section 26 inches broad by 5 inches deep, and through this part the empty half of the web is always passing. The whole retort is made of boiler plate, and has no lids or other openings except that at the base of the hopper where the coal is supplied to the web. At the opposite end of the retort is fixed the stand-pipe for carrying off the gas, and at this end also is a pipe descending

downwards for carrying off the coke or carbonized coal as it drops from the web in passing round the drum at this end.

It will be observed, that all the processes connected with this retort, including both the charging with coal and the emptying out the coke, are performed by machinery without the aid of manual labour. The system has yet further advantages.

The very thin stratum of coal distributed on the plates of the web occupies fifteen minutes in passing through the carbonizing part of the retort, which is 7 feet in length by 2 feet wide. Hence about 744 cubic inches of coal, or 21 lbs. in weight, occupy a heated surface of 2016 square inches, or nearly 100 square inches for every pound of coal. The consequence of this great heat so judiciously applied is the production of gas in greater quantity and of higher specific gravity than that made in the ordinary way. The working of this retort is said to yield 5·36 cubic feet of gas for each pound of Wall's End coal, or at the rate of 12,000 cubic feet per ton. The specific gravity of the gas will be about ·490. Each retort will carbonize about 18 cwt. of coal in twenty-four hours, whereas few retorts of the same length, worked on the old plan, will carbonize more than half this quantity. Mr. Clegg states, that the coke is increased in this process about 75 per cent., but although better for culinary use than the ordinary coke, it is not so well adapted for general purposes.

The cost of materials and workmanship for erecting a bench of four retorts, each with a revolving web, will be about £150, and their performance will be equal to 43,200 cube feet of gas of specific gravity ·480 in twenty-four hours. A bench of five D retorts on the ordinary plan will not cost more than £40, and will produce in twenty-four hours about 14,000 cube feet of gas of specific gravity ·400, so that the first cost of the web retorts, in proportion to the quantity of gas produced, is somewhat greater than that of the old form. Supposing the wear and tear to be eqnal, however, the annual expenditure is mnch less for the new form. To take down and replace a bench of five D retorts will cost nearly £35, or at the rate of 52*s*. for

every 1000 feet of gas produced in twenty-four hours, whereas the cost of replacing all the parts subject to wear and tear in the web retorts will not exceed £44, or at the rate of 20*s.* for every 1000 feet of gas produced in twenty-four hours. Taking, then, the extra first cost into consideration, the saving in materials and workmanship by using the web retorts would be at least half; in addition to which, fewer men are required to work them.

Mr. Clegg expresses a very high opinion of these retorts, and says unhesitatingly that he should adopt them if he were to become the lessee of any gas-works. He states, among their minor advantages, that the retorts occupy less space, require fewer men and tools to work them, that the laborious work of the stokers is almost dispensed with, that the retort-house would be free from the heat and suffocating vapours which are so much felt at present, and might be kept always perfectly clean and wholesome. He observes also a curious fact with reference to the iron plates of which the web is composed,—namely, that by their contact with coal at a red heat and in a close furnace, the plates absorb carbon and become converted into steel, which may be sold for a sum sufficient to construct a new web.

Notwithstanding the apparently theoretical advantages of these retorts, however, the practical man will receive with caution statements which have not been confirmed by the test of experience. Objections may also arise out of the supposed complication of the machinery for working these retorts, the number of stuffing-boxes required for the double set of shafting, and from other details. On the whole, it seems desirable, if possible, to give a trial to retorts on this principle, more especially as it seems practicable, from an inspection of the drawings, to add to their efficiency without any great increase of expense. It will be observed that only one part of the retort-chamber is used for carbonizing, namely, the upper straight part constituting the retort proper. If the structure could be so arranged that the furnace should act also on the

lower part of the retort-chamber, and the now empty part of the web could receive its charge from another hopper, it is evident that a double process of carbonization would be effected. I offer this hint, however, with hesitation, as it has not been worked out, but arises merely from a consideration of the general principle involved in this mode of distilling coal.

CHAPTER VI.

MODE OF SETTING IRON RETORTS.

In the manufacture of gas, as in all other branches of industry, there has been a gradual and successive improvement ever since its first introduction,—an improvement tending on the one hand to increase the brilliancy and efficiency of the light, and, on the other, effecting economy in the working. To no part of the process does this remark more directly apply than to that connected with the retorts, which form so important a part of the distillatory apparatus. We have seen that Dr. Henry, in his experiments on the Lancashire cannel coal, was only able to procure about 6000 feet per ton, whereas from a far inferior coal nearly all the great London Companies are at this moment procuring on the average nearly 9000 feet. No doubt some part of this large increase is due to the magnitude of the operations, as we do not find a proportionate quantity of gas made in small country works. At the same time it must be admitted, even from the increased produce of gas during late years, that a great deal depends on the construction of the furnaces and flues, the mode of setting the retorts, and the proper regulation of the heat.

In fixing on the mode of setting the retorts, of course a great deal must depend on the quantity of gas required to be produced, as the retorts for small gas-works are set in a much

simpler manner than those at the large metropolitan works, where from a million to a million and a half feet of gas are required to be sent out per night in midwinter.

The principal considerations in setting retorts are the size and shape of the furnace and the arrangement of the flues.

Figs. 21 and 22 are a cross section and longitudinal section of the form of furnace recommended by Mr. Clegg in his 'Treatise on the Manufacture of Coal Gas.' In these figures *a* is the arch over the coke vault, which is usually underground; *b* is a pan placed at the bottom of the ash-pit and used for evaporating ammoniacal liquor; *c c* are the piers or sides of the furnace, half a brick thick, and built of fire-brick; the width of the furnace or space between the piers, *c c*, varies

Fig. 21.

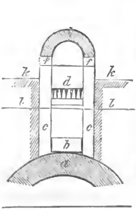
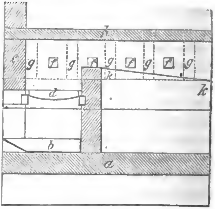


Fig. 22.



with the number of retorts to be heated by the furnace. For heating one retort, Mr. Clegg makes the width 10 inches; for two retorts, 12 inches; and for heating a bench of five retorts, 14 inches. *d d* are the furnace-bars, the length of which also varies with the number of retorts; thus for one retort 5 fire-bars, each 10 inches long, would be required; for two retorts, 6 fire-bars, each 14 inches long; and for five retorts, 7 fire-bars, each 2 feet long. Thus the area of grate for heating one retort would be 100 sq. inches; for two retorts, 168 sq. inches; and

for five retorts, 336 sq. inches. The fire-bars employed by Mr. Clegg are usually V-shaped, $1\frac{1}{4}$ inch wide at top and $\frac{1}{2}$ an inch at bottom; their form is fish-bellied, $2\frac{1}{4}$ inches deep in centre and $1\frac{3}{4}$ inch at the ends; they are placed with their upper surfaces about $\frac{1}{2}$ an inch apart. *e* is a 9-inch wall in front of the retorts; *f f f f* are four openings, of 3 inches sqnare, to admit the heat of the furnace to the under side of the retorts. Where only one retort is to be heated, these openings are unnecessary. *g g*, in fig. 22, are fire-brick walls, $4\frac{1}{2}$ inches thick, carried up on each side of the arch *h*, to support the retorts where more than one has to be heated; *h* is the fire-brick arch of the oven; *k k* shows the height to which the solid brick-work is carried, and *l l* is the firing floor or level of the ground surface in the retort-house. When the retorts are set singly, according to Mr. Clegg's plan, each retort is placed either immediately on the arch, *h*, which is cut flat to receive it, or rests on a fire-tile placed on the arch. The retort is enclosed in an oven about 4 inches greater in diameter than the retort itself, and is so placed that a flue space of 6 inches is left between the retort and the arch of the oven. The heat from the furnace passes along under the arch *h*, and arriving at the end of the retort passes up at the back of it, the end of the retort being protected by a fire-brick from the direct action of the heat: it then returns along the top of the retort, being confined by the arch of the oven, and when again arrived in front of the retort passes through a 6-inch square opening in the top flue, which is also about 6 inches square, and which conveys the heat to the chimney, or, in larger works, to a main flue. Mr. Clegg recommends the retorts to be set singly on this plan in small towns where the consumption of gas does not exceed 10,000 cube feet per night in midwinter. Small D retorts, charged with Newcastle coal at the rate of 140 lbs. every six hours, would each produce about 2000 feet of gas in twenty-four hours, so that five of such retorts in action would be sufficient for such a supply.

In towns where the consumption varies from 10,000 to 30,000 feet in twenty-four hours, Mr. Clegg recommends two retorts to

be set in each oven. These are to be set on fire-tiles, the bottom of each retort being on the level of the crown of the arch *h* in figs. 21 and 22. The retorts may be placed 6 inches apart, a space of 2 inches being left between the retort and the sides or piers of the oven. In this mode of setting, the heat passing from the furnace through the openings *ff* diffuses itself beneath the retorts, and passes up at the outsides into the space above them. The arch of the oven confines the heated air to a considerable extent, but has four openings to allow it to escape into a longitudinal flue built over each oven. Each of these longitudinal flues is provided with a damper and opens into a larger main flue, which communicates with the central chimney and passes transversely to the range of ovens, however many there may be.

In works where the production of gas exceeds what has been stated above, Mr. Clegg recommends benches of five retorts set in ovens with semicircular arches 6 feet in diameter, the ovens to be built back to back, and separated by a 14-inch brick wall, on each side of which are the two main transverse flues before described, and which in large works require to be at least 18 inches diameter. In setting five retorts in one oven, according to Mr. Clegg's method, the three lower retorts rest on fire-tiles, as before, at the level of the crown of the arch *h*, and are placed 6 inches apart, the fire-tiles being supported on the cross-walls *g g*. The two upper retorts rest on the front wall and on fire-brick pillars, 9 inches by 4½, carried up between the three lower retorts and surmounted by a fire-lump. The arrangement of the flues is the same in this case as where two retorts are set together. The heat passes as before through the four openings *f*, and after circulating beneath the lower retorts and passing up outside them to heat the upper retorts, which do not require the protection of fire-tiles, it escapes through four openings in the arch of the oven into the longitudinal flue, 12 inches square, which is built over each bench, and thence into the main transverse flue which leads to the central shaft or chimney.

The D retorts referred to in this description of setting are of intermediate size, 7 feet long, with a cross section of 14 inches by 14 inches. These retorts are charged with a cwt. and a half of coal every six hours, so that each retort carbonizes 6 cwt. in twenty-four hours, and the whole bench of five retorts carbonizes 30 cwt. of coal in twenty-four hours. To produce this effect the area of the fire-grate is, as we have seen, 336 square inches.

Mr. Peckston, the author of a well-known popular treatise on Gas-Lighting, gives numerous examples of retort-setting, from which the following particulars are abridged. His area of fire-grate for six retorts, each 12 inches square in section and 6 feet long, set horizontally side by side and heated by a furnace at one end, is 384 square inches, the fire-bars being 2 feet long and the grate 16 inches wide. The sides of this furnace are upright. Rectangular retorts, 8 feet long, area 20 inches by 9 inches, set singly, each in an oven, and each heated by a fire with a grate of 450 square inches; sides of furnace upright. A bench of three large York D retorts, each 6 feet long, area 20 inches by 12 inches, heated by a furnace with a fire-grate 33 inches by 12 inches wide, or with an area equal to 396 square inches. This furnace is convertible into a coke oven, so that coke of the best quality may be made while the coal is being carbonized. In a setting of five cylindrical retorts in one oven, each retort being 6 feet long and 12 inches diameter, is an example of a splayed furnace, the width at the fire-bars being 11 inches, which is splayed out to 4 feet wide at a height of 6 inches above the surface of the grate. The area of grate in this setting is 273 square inches. The last example to be quoted from Mr. Peckston is also a splayed furnace, for heating three retorts set in a bench. The retorts are D-shaped, 5 feet long, area 12 inches by 12 inches, and the fire-grate has an area of 144 inches only, being 18 inches long and 8 inches wide. The sides, however, at 6 inches above the fire-bars begin to splay out, and the space increases in width till under the lower range of retorts it is 5 feet wide.

In the Philadelphia Gas-Works, which may be taken as a good example of most matured judgment and experience, derived from a very accurate examination of nearly all the principal gas-works in England, we find a furnace with upright walls and an area of grate equal to 504 square inches, the grate being a foot wide and the fire-bars $3\frac{1}{2}$ feet long.

This furnace heats three large York D retorts, 7 feet 6 inches long, 20 inches wide, and 12 inches deep. These retorts are calculated to carbonize 120 lbs. of coal every four hours, which is equal to 720 lbs. for each retort in twenty-four hours, or 2160 lbs. or 19 cwt. for the whole bench. Mr. Clegg gives an area of only 336 square inches to a furnace for carbonizing 30 cwt. of coal in twenty-four hours, whereas the Philadelphia Works have 504 square inches for carbonizing only 19 cwt. So various are the practices in gas-works.

In the Philadelphia Works the mode of setting the retorts is somewhat different from that of Mr. Clegg. The cross flues correspond with the spaces between Mr. Clegg's transverse walls, but the heat after having circulated between the retorts and the arch of the oven escapes not by passing through this arch but by a flue at the back of the retorts; and in this flue, which communicates with a main transverse flue, a damper is placed for each bench of retorts.

Figs. 23 to 26 show the details of setting the retorts at the Philadelphia Gas-Works.

Fig. 23, on a scale of 1 inch = 3 feet, is an elevation of a bench of three retorts set in one oven. R R R are the retorts, D the fire-door of the furnace, M the hydraulic main, and S the stand-pipes.

Fig. 24, on the same scale, is a longitudinal section through the oven, showing the upper and lower retorts in elevation, also the arrangement of flues, the length of furnace and fire-bars, and the connecting pipes between the retort and the hydraulic main. In this figure the same letters of reference are used as in fig. 23.

Fig. 25, on a scale of 1 inch = 2 feet, is a cross section

Fig. 23.

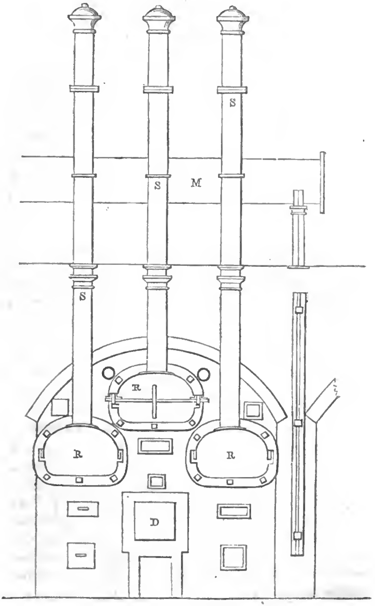
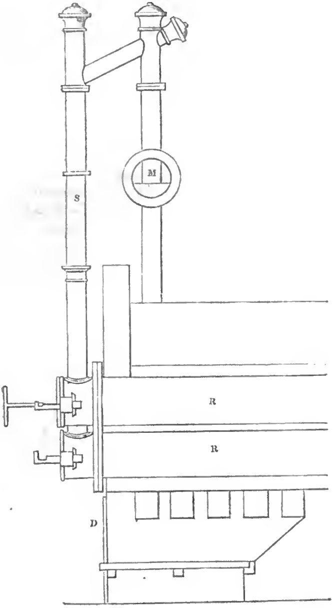


Fig. 24.



showing the mode in which the retorts are set on fire-tiles, the arrangement of the flues, and the breadth and height of the furnace.

Fig. 26, on the same scale as the last, is a plan showing the furnace and the arrangement of the flues and cross walls.

Most of the French gas-works have furnaces with upright walls, and the dimensions of the fire-grates correspond very nearly with those which have been quoted from Mr. Clegg's work.

Mr. Croll, however, who seems destined to create a great revolution in many of the practices of gas-engineering, has adopted a furnace of a different character from any we have been considering. The great peculiarity of Mr. Croll's management consists in heating iron and clay retorts by the same furnace, applying the heat first to the clay retorts and finally to the iron retorts, when its ntensity is somewhat modified. The engravings, which hereafter will be more particularly referred to, furnish examples of Mr. Croll's system applied to small provincial

Part of fig. 24.

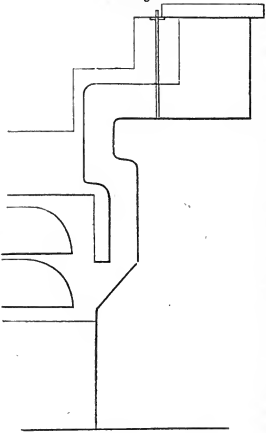
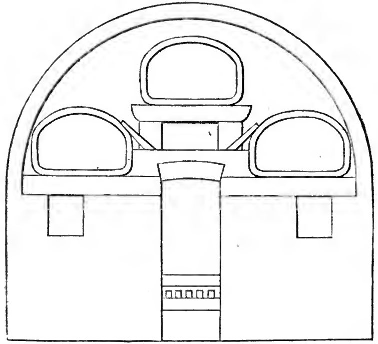


Fig. 25.—Section showing the mode of setting Retorts at the Philadelphia Gas-Works.



works, as those at Winchester, and again in a case where the works are of great magnitude, as in those of the Central Gas Consumers' Company at Bow Common. It will be seen from an inspection of fig. 27 (scale 1 inch = 2 feet) that Mr. Croll's fire-place even for heating thirteen retorts, each 9 feet long, is only 6 inches wide at the fire-bars, being splayed out to 16 inches at a height of 2 feet above the grate. His fire-bars are $3\frac{1}{2}$ feet long, only two in number, and consist of mere bars of iron, 2 inches square, laid loosely on the bearing-bars, so that they can be raised and clinkered whenever required.

In some of Mr. Croll's furnaces a single round bar has been adopted for the fire-grate instead of two square bars. It is said that the round bar presents the advantage of being more easily cleaned from clinkers than the square form. The ash-

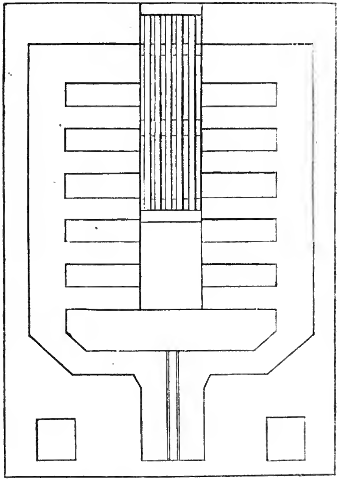
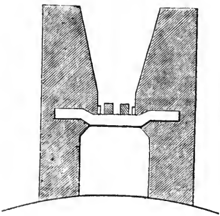


Fig. 26.—Plan of Furnace at the Philadelphia Gas-Works.

pans below the fire-grate are supplied with water, the evaporation of which keeps the fire-bar cool. This furnace is not closed over at all, but the heat circulates at once amongst the clay retorts, and then passes down into the lower oven amongst the iron retorts, and is finally conveyed away by means of a flue passing under the latter. Modifications of this method are seen in our engraving of the Works at Winchester, where in some benches the iron and clay retorts are set in the same oven, but the heat is still made to act first, and with its

Fig. 27.



greatest intensity, on the clay retorts. The splaying out of the walls of the furnace, their great thickness, and the mass of coal concentrated in an incandescent state are considered to give this furnace a great superiority over other shapes. The amount of coal carbonized by one of Mr. Croll's large double benches is probably not less than $8\frac{1}{2}$ tons in twenty-four hours; namely, 5 tons in the clay retorts, and $3\frac{1}{2}$ tons in the iron. This large carbonization is effected with two furnace-grates of only 252 square inches each, or 504 square inches in all. The economy of fuel in this furnace is also said to be very remarkable, for while most of the Metropolitan works require nearly one-third of all the coke made to carry on the carbonizing process, it is said that only 12 per cent. is used at Bow Common.

The method of enclosing two or more retorts in arched ovens is due to Mr. Rackhouse, who in 1815 constructed a set of retorts on this principle. This mode of setting is a great improvement on the old plan of placing several retorts to one fire, and conducting the flues round them. The heat thus communicated was never uniform, and some parts of the retorts were constantly burnt out, while others were scarcely touched by the heat. In the oven plan great uniformity of

heat is attained, and the retorts are further much protected by the use of fire-tiles, and of fire-lumps to protect the ends.

In large establishments where 100 or more retorts are used the mode of setting in ovens is now universally practised, the number of retorts in each oven varying from three to nine.

The system of setting up benches of retorts *adossés*, or placed back to back, is now coming much into practice; but Mr. Croll's Works at Bow is the only place where we have seen iron retorts set in one long double length of 20 feet. Mr. Croll, however, claims a considerable advantage from being able to charge both ends of these long retorts at the same time, and if these advantages are realized, we shall probably see the system extended to iron retorts as well as to those of clay, which are frequently set in one length of 18 or 20 feet.

FURNACE-DOOR AND FRAME.

The front of the furnace has an iron frame or plate, which Mr. Clegg makes an inch and a half thick, 2 feet 6 inches long, and 26 inches wide. To this frame the fire-door is hinged, and in the centre of it, about 6 inches above the door, is a square opening for the admission of a spout when tar is to be burnt with the coke in the furnace. For an oven containing five D retorts, such as already described, Mr. Clegg makes the door 15 inches by 11 inches, and $\frac{3}{4}$ths of an inch thick; hinge-eyes $\frac{7}{8}$ths of an inch diameter, fitting the hooks cast on the frame. The fire-door has a dove-tailed projecting recess on the inside, fitted with a fire-brick 3 inches thick, in order to protect the door from the action of the great heat to which it is subject. The door is provided with a wrought-iron latch working in a keeper cast on the frame.

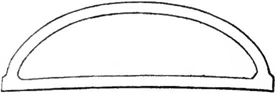
Mr. Croll's doors and frames are very similar, but of rather smaller dimensions. The frame is 18 inches square and only one inch thick. The door is 9 inches × 13, with half an inch overlap all round, and $\frac{3}{4}$ths of an inch thick; the projecting recess fitted with a fire-brick 2 inches thick.

CHAPTER VII.

FIRE-CLAY AND BRICK RETORTS — WROUGHT-IRON RETORTS.

It appears that the introduction of retorts made of burnt clay as a substitute for cast iron is due to Mr. Grafton, who took out a patent in 1820 for the use of clay retorts. The form first used was that of a square, which was erected at Wol-

Fig. 28.



verhampton, but the form was afterwards altered to that of a broad shallow D, and this shape has been used by Mr. Grafton for many years, and applied in numerous gas-works both in this country and on the continent. (See fig. 28.)

Mr. Grafton's retort is 5 feet wide and 18 inches high, made in short lengths of about 16 inches, and jointed together with fire-clay, so as to form an oven 7 feet long. These retorts are capable of carbonizing at the rate of 7 cwt. of coal in six hours, or more than five times the quantity carbonized by the small D-shaped iron retorts. Since the introduction of Mr. Grafton's clay retorts this material has been used in a variety of shapes. In Scotland especially, notwithstanding the cheapness of cast iron, nearly every form and size of which iron retorts are made have been applied to those of clay. D-shaped retorts of all sizes,—square, circular, and elliptical,—have all been tried, and generally the success which has attended them in Scotland has been remarkable.

In London also the clay retorts are decidedly gaining ground, but their shape and size are materially different from

those employed by Mr. Grafton. They are made in lengths of 6, 7, and 8 feet, with a circular or elliptical section, and an area of about 200 square inches.

At the Phœnix Gas-Works the clay retorts are used on an extensive scale; their mode of setting and management reflect great credit on the able superintendent, and their performance is highly efficient. The retorts used there are 20 feet in length and 16 inches diameter, composed of three pieces jointed together with fire-clay. They have a mouth-piece at each end, and are set seven to one bench. The charge is a ton of coals at each end, so that one bench of retorts will carbonize 8 tons in the twenty-four hours. Elliptical clay retorts of about the same sectional area as the circular ones are also used at these Works. The yield is at least 9000 feet of gas per ton of coal, with the additional advantage of much greater durability in favour of the clay retorts.

At the City of London Gas-Works also preparations are being made on an extensive scale for the trial of clay retorts in single lengths, and they are now being set in various forms.

CLAY RETORTS IN SCOTLAND.

A clever correspondent of the 'Gas Journal' describes the mode which he has himself adopted for setting clay retorts after trying a variety of methods, none of which succeeded so well as the one he has eventually adopted. His retorts are 7 feet 6 inches long, made in two lengths: he sets three retorts in one oven, namely, two D retorts, each 15 inches wide and 14 inches high, and one circular retort 15 inches diameter. The retorts are set in a semi-elliptical arch with the transverse or longer axis vertical, the width of the arch being 5 feet, and the height 3 feet 6 inches.

The fire-bars are laid on the level of the floor, which is paved with fire-bricks laid on edge. The furnace is 3 feet 9 inches long and 12 inches wide, splayed out to 18 inches at the height of 9 inches above the floor, and from that point the walls are carried upright. The front of the oven is half a

brick in thickness, and the back 9 inches. Two 14-inch cross-walls are carried up to the height of 27 inches above the floor line to support the two lower retorts, which rest on these cross-walls and on a 4½-inch wall carried up inside the front and back walls of the oven. The furnace is arched over by a flat brick arch, which springs from fire-brick lumps laid as springers on the cross-walls. The crown of the arch is level with the under side of the lower retorts.

The circular retort rests on a brick pillar 9 inches square, carried up at the end of the furnace arch and resting on it. The height of this pillar is 18 inches, and the retorts are so arranged that a space of about 3 inches is left between the circular retort and the lower D retorts. The front and back ends of the circular retorts are supported by 4½-inch walls like the lower retorts. Fire-lumps are also interposed between it and the lower retorts as a further support for the upper one. In the arch of the oven are two 6-inch openings into a longitudinal flue, one opening being 9 inches from the front of arch, and the other within a foot of the other end. The top or longitudinal flue is 12 inches square, and is provided with a damper.

This bench of three retorts will produce on an average 95,000 feet of gas weekly, which is fully equal to the production from a bench of five 14-inch D retorts. Mr. Clegg estimates the cost of such a bench at £38. 3*s.*, whereas the renewal of a bench of three clay retorts will not exceed the following.

	£.	*s.*	*d.*
Taking down old retorts and clearing out oven .	0	10	6
Three new retorts laid down at works, at 84*s.* .	12	12	0
600 fire-bricks, at 10*s.*	3	0	0
Fire-clay tiles, lumps, &c.	1	5	0
Wages to bricklayer, fitting on mouth-pieces, building and setting in retorts, repairing flues, &c. .	2	2	6
Repairing bolts and screws, making good connections, &c.	1	7	6
	£20	17	6

It is usually considered that the durability of clay retorts is much greater than iron, and there are many Works in Scotland where clay retorts are said to have made a million and a half cubic feet, whereas the duration of an iron retort is commonly measured by a production of 800,000 cubic feet.

Fig. 29.

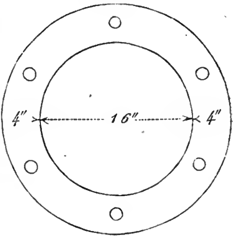


Fig. 29 shows the open end of a clay retort, and fig. 30 shows the mode of attaching the mouth-piece by means of bolts with T heads let into the body of the retort.

Fig. 29 is a front elevation of the retort, showing the thickness of the part to which the mouth-piece is bolted, and also the bolt-holes, an inch and an eighth diameter.

Fig. 30 is an elevation showing the mouth-piece attached, with a socket-pipe bolted on, but without the lid, which may be similar in its details to that shown for iron retorts.

Fig. 31 is a front elevation of one of the pieces of which the retort is composed, showing the triangular groove; and

Fig. 32 is a section showing the junction between two pieces of the retort.

In preparing the end of the retort to have the mouth-piece attached, the end surface is chipped and notched with grooves like the surface of a millstone, in order to retain more firmly the cement filled in between the retort and the flange of the mouth-piece. The cement used is the ordinary iron cement compounded without sulphur and mixed with an equal quantity of fire-clay. This mixture, made into the consistence of mortar, is spread evenly over the joint; the mouth-piece is

Fig. 30.

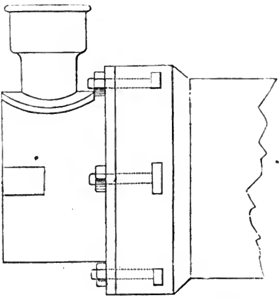


Fig. 31.

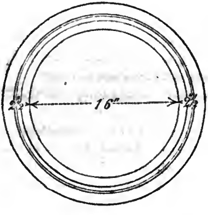
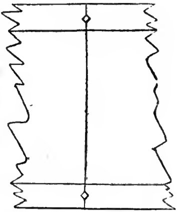


Fig. 32.



then attached and screwed up, the recesses in which the bolts are sunk being filled with the same mixture. The centre

joints, as well as that of the end piece where this is separate, are made with a similar compound of fire-clay and iron cement. At these joints also the parts which come in contact have a small triangular groove cut in them, as shown in figs. 31 and 32, and the cement being squeezed into this groove hardens, and forms a dowel, which adds considerably to the strength of the joint.

The cement used in the Works of the Imperial Continental Gas Company, where several hundreds of clay retorts are employed, is said to be somewhat different from the ordinary iron cement. For jointing the mouth-pieces of clay retorts they use a mixture composed of 20 lbs. of gypsum made into a pulp with water, and added to 10 lbs. of iron borings saturated with a strong solution of sal ammoniac (muriate of ammonia). For the joints between the separate lengths of clay retorts the proportion is altered to 10 lbs. of gypsum and 20 lbs. of iron borings, mixed together with a solution of sal ammoniac to the consistency of ordinary mortar.* Some time should be allowed for the work to dry before the clay retorts are heated, though some engineers who have adopted clay retorts speak of using them very soon after they are put up.

The correspondent of the 'Gas Journal' before referred to, in speaking of the leakiness sometimes caused in the joints of the mouth-piece and the upright pipe by the expansion of the retorts, recommends a composition which he has himself used very successfully,—namely, a mixture of moist chalk or whitening, with half its weight of common salt, compounded with water into a plastic state, and applied like glaziers' putty.

A great difference of opinion still exists with reference to the respective merits of iron and clay retorts. In Scotland the latter are very generally used, and in England they are certainly gaining ground. It appears to be generally admitted that they require a higher working heat than iron, for while the latter work most satisfactorily at a cherry-red heat, the clay retorts perform best when a white heat of several

* 'Journal of Gas-Lighting.'

hundred degrees greater intensity is applied. The advocates of clay retorts contend that this greater intensity of heat decomposes, and converts into gas, matter which with a lower heat would pass off in the shape of tar, while the opponents of clay retorts do not hesitate to compare them to an apparatus for decomposing olefiant gas and converting it into light carburetted hydrogen. If it be admitted, however, that clay retorts yield a greater quantity of gas than iron, it can hardly follow that this presumed decomposition of olefiant gas is the cause of the increased quantity, because Dr. Fyfe, whilst leaning himself rather to the side of iron retorts, has very candidly admitted that the volume of gas is by no means increased when olefiant gas is converted into light carburetted hydrogen. As olefiant gas contains twice as much carbon as carburetted hydrogen, the conversion takes place by the deposit of half its carbon, but the volume of carburetted hydrogen which remains is only equal to that of the olefiant gas, and not double in quantity, as has been erroneously supposed by some writers on the subject. Dr. Fyfe is nevertheless of opinion that the large quantity of carbon deposited in clay retorts is due to the decomposition of olefiant gas, and he estimates that every 225 grains of carbonaceous deposit indicates the decomposition of 1 cubic foot of olefiant gas; and he estimates that under ordinary circumstances 16 lbs. of carbon are deposited in a single clay retort per month. After all, it has not been clearly shown that the gas from clay retorts is inferior in illuminating power to that from iron, while it appears to be generally admitted that the quantity of gas produced is greater.

The consumption of fuel is another point which is much disputed, the one party contending that a much higher per centage is required for carbonizing with clay retorts, while the other party insist that the expense per 1000 feet of gas is less with clay than with iron retorts.

A great deal has been said and written on the porosity of clay retorts; and even some of those who think highly of them

and recommend their adoption, contend that a great escape takes place by leakage even for months after they are first brought into use. They allege that the porosity is proved by finding in a fractured retort, which has been some months in use, the whole mass of the thickness coloured by carbonaceous matter which has insinuated itself into the pores. On this side of the question experiments are referred to where 15 cwt. of coal were distilled in iron retorts which had been six months in use, and the same quantity in clay retorts which had been one month in use.

	cubic feet.
The produce from the iron retorts in 5 hours was .	9064
And from the clay retorts	8000
Difference in favour of iron	1064

The clay retorts yielded considerably less in the first hour, the difference being less in the second, still less in the third, while in the fourth hour each kind of retort yielded alike, namely, 1400 feet; in the fifth hour the clay retort yielded 900 feet, the iron 700 feet.

The difference in the result is said to be due to the absorption of gas or leakage in the clay retorts, which was proved by trying the absorption at different pressures. From this experiment it appeared that the iron retort at a working pressure of 11 inches leaked 489 feet, and the clay 1540 feet, the difference being 1051 feet, which is sufficiently near to 1064 feet, the difference actually found in their productive power. In the carbonizing experiment a greater heat was applied to the clay retorts than to the iron. The same parties who thus insist on the porosity of clay retorts and their inferior performances at first, will admit, however, that after six months' work the pores become stopped up; and, while they insist on the necessity of removing the pressure as much as possible from the clay retorts, have admitted, that from cannel coal, at least, clay retorts working under low pressure are able to produce 10,000 cubic feet of gas per ton.

The strenuous advocates of clay retorts on the other hand

contend, that this porosity does not exist in good retorts, — at all events, that it does not produce the diminished consumption here spoken of: they assert, that even with a pressure of 28 inches on the retorts in winter and 22 inches in summer, without the use of an exhauster, so little leakage takes place that the retorts attain the standard of production in twenty-four hours after they go to work. On this side of the question many examples are referred to of clay retorts carbonizing 7 cwt. of coal in twenty-four hours, and producing gas at the rate of more than 10,000 and even 11,000 feet per ton. The works referred to are principally those where the Scotch Parrot coal or Lancashire cannel is used.

The average expense for wear and tear is another severely disputed item. The detailed estimate given above for setting a bench of three fire-clay retorts appears reasonable; and the same writer gives a detail during several years, showing that the wear and tear of clay retorts has not exceeded 1½*d.* per 1000 feet of gas manufactured. Estimates which have been made at various times by Mr. Clegg and Mr. Barlow would lead to the conclusion that the wear and tear of iron retorts is at least 2*d.* per 1000 feet. Many exaggerated statements appear to have been made as to the relative economy of iron and clay retorts, in the advertisements issued from time to time by the manufacturers of the latter. These we shall pass by;—the following facts with reference to clay retorts appear more worthy of notice: at a Scotch Gas-Works where cannel coal is used, and the works are on a very small scale, there are two clay retorts which have each made 430,000 feet of gas in three months. These retorts are only 5½ feet long, 20 inches wide, and 13 inches high.

This is equal to a production of 4725 feet in twenty-four hours, and as a ton of coal at these works produces 8561 feet of gas, it follows that each retort must have carbonized at the rate of 11 cwt. in twenty-four hours. It should be observed that where cannel coal is used, heavier charges may be put in the retorts than where caking coal is employed; in the first

place, because the coke does not swell so much,—and secondly, because the coke does not present such an impenetrable coating to defend the inner mass of coal. From these causes larger charges of cannel coal may be used.

Another example may be quoted of the great success attending the use of clay retorts: at the South Metropolitan Works it was stated some time ago in the 'Journal of Gas-Lighting,' that two benches with five clay retorts in each had been uninterruptedly in action for upwards of 17 months. They are D-shaped, 20 inches by 12½ inches high, and 7½ feet long. These retorts have produced to the present time 1,800,000 feet of gas per retort, with an expenditure of fuel not exceeding that of iron retorts: they are made in one piece by Cowen & Co., of Blaydon House, near Newcastle-on-Tyne.

Mr. Barlow estimates the duration of iron retorts equivalent to the production of 700,000 cubic feet of gas.

SPINNEY'S BRICK RETORTS.

Some years ago Mr. Thomas Spinney, of the Cheltenham Gas-Works, adopted a brick oven for the direct carbonization of coal in gas-making. The dimensions of the oven are 3 feet 2 inches wide, 8 inches deep to the springing of the arch, and thence to the soffit or crown 6 inches. The bottom and sides were formed of Newcastle fire-tiles, the arch of fire-bricks made of the best Stourbridge clay, mixed with 10 per cent. of sharp river-sand and pipe-clay to prevent the bricks from cracking. The oven was 7 feet in length, exclusive of the mouth-piece, and the usual charge was 5 cwt. of Welsh coal, from which about 2400 cubic feet of gas were said to be obtained, or at the rate of 9600 feet per ton, the usual produce of the same coal distilled in iron retorts being under 8000 feet per ton. As the charge required to be drawn only once in twelve hours, Mr. Spinney adopted in connection with these ovens a method of separately sealing the stand-pipe from each oven by a cup-valve acted on by a lever. There would be a

great objection, in the ordinary mode of working, to the use of such separate valves, owing to the frequent care and attention they would require; hence the almost universal adoption of the method of sealing the dip-pipes by the tar in the hydraulic main. This objection is, however, much modified, when, as in Mr. Spinney's mode of working, the valve only requires to be closed during the drawing of the charge once in twelve hours. The great objection to the brick ovens, however, arose from the large quantity of fuel required for carbonizing. Where coal was used for heating the furnaces, 50 per cent. of the quantity distilled was required for fuel, and where coke was used, three-fourths of the quantity made was used, so that only one-fourth of the coke was left for sale.

Mr. Spinney's brick retorts have now been in use for twenty years, and the reports I have received from Cheltenham, Exeter, and Newport (South Wales), in which places they are employed to the exclusion of all others, speak of them in very favourable terms. The usual charge is 5 or 6 cwt. of Newcastle or Welsh coal every twelve hours. The quantity of gas made with one ton of Welsh coal is about 9000 cubic feet, and with Newcastle coal from 10,000 to 12,000 cubic feet. In Cheltenham the Gas Company has peculiar disadvantages to contend with, the price of labour being excessive, sale for coke very limited, and many miles of main laid down without a single private lamp, the proportion of public lamps to the gross rental being greater than in any other town in the kingdom. With all these drawbacks against the profitable manufacture of gas, the price to the private consumer is only 5*s*. per thousand feet, and yet the dividend to the shareholders has lately been 8 per cent., with a bonus of 2 per cent. in addition.

In Exeter the brick retorts have been used for nearly twenty years, and although many additions have been made to the works from time to time, these retorts have gradually superseded all others, and in fact no others are now in use. The brick ovens have been at work constantly for ten or eleven

years without requiring to be taken down, and the only annual expense is a trifling repair to the flues and fire-places.

At Newport the brick retorts have been in use eight years, and none of them have yet been taken down, Mr. Bryan, the manager, believing they will last two or three years longer. The original cost of erecting each retort is £50 or £60, and the annual repairs something less than £5. At Newport they make 15 cwt. of coke from a ton of coal, the quality being superior to that usually made in iron retorts.

The chief advantages claimed by the inventor of brick retorts are the regularity and uniformity with which they work, and the expense saved by the hydraulic valve, which renders an exhauster unnecessary, the pressure on the retorts being only equal to a column of 4 inches of water.

Amongst the minor advantages may be mentioned the diminution of labour, which in the department of stokers is said to be one-third less than in the ordinary system; that is to say, owing to the long interval of charging once in twelve hours, two stokers will do the work of three, and with far less prostration of physical strength. As an illustration of the comparative lightness of the labour, it may be mentioned, that when any accident has prevented the night-stokers from coming on at their proper time, the day-stokers have worked on through the night,—an exertion which would be scarcely practicable, had their physical strength been impaired by their first day's work.

Mr. Clegg draws a comparison between Mr. Spinney's retorts and the ordinary iron D, and makes the cost of fuel and wear and tear somewhat in favour of iron retorts. In this estimate he assumes that two of Mr. Spinney's ovens will carbonize two tons of coal in twenty-four hours, and that the same quantity will be carbonized by a bench of five large York D's; produce from the iron retorts 8000 feet of gas per ton, with 25 per cent. of coal as fuel, and from the brick ovens 9000 feet of gas per ton, with 50 per cent. of fuel. I believe this comparison is scarcely fair towards the brick ovens, inas-

much as the quantity of fuel is assumed too high in the case of the brick ovens. Mr. Spinney states that the quantity required for carbonizing in his ovens is now reduced to 42 per cent., and where coke is used for carbonizing, 680 lbs. are required for 12 cwt. of coal, or at the rate of two-thirds of the coke produced.

CLIFT'S BRICK RETORTS.

Another description of fire-brick retort has been used for some years by Mr. J. E. Clift, and has recently been described in a paper read before the Institution of Mechanical Engineers. Mr. Clift's retorts are made of two different sections, namely, a large size of the D-shape, 5 feet 3 inches wide and 18 inches high, and a smaller D-shaped retort 15 inches wide and 15 inches high. These retorts are built of fire-bricks, two of the small ones and one large one being set in a bench. The retorts are 20 feet long, and are charged and fired at each end. The fire-bricks which form the bottom and sides of the small retorts and the bottom of the large retorts are 16 inches long and 3 inches thick, while the arch bricks of the retorts are 9 inches long and 3½ inches thick. Each brick is rebated an inch deep at two of its joints, and has a dowelling triangular groove at the other two joints, which being filled by a tongue of hard fire-clay adds much to the strength of the retort. The two lower retorts are placed one on each side of the furnace, the level of the fire-bars being 12 inches below the bottom of these retorts. The upper retort is placed over the two lower ones, and fills up the whole space of the oven with the exception of a few inches on each side. The furnace is 3 feet 6 inches in length and 15 inches wide, with upright sides. The heat circulates beneath and around the lower retorts, and plays on the bottom of the large retort, from which it is not then suffered to escape, but is conducted through a series of flues placed around the arch of the upper retort. Of this series of small flues there are four on each side of the retort, and one over the middle of it which conveys the heated air to the

main flue. The heat which passes up from the lower retorts proceeds along the two outside flues to the back of the large retort, and returns along the two next flues to the front, and so on through the four flues on each side, when the heated air from each side meets in front of the retort and passes along the middle flue to the main flue. As the retorts are 20 feet long, and the oven is divided by a wall in the middle, it follows that each flue will be 10 feet in length, and the heat will consequently have to pass over 50 feet of the surface of retort from the time it leaves the furnace till it reaches the main flue.

The space between the upper retort and the arch of the oven is 4½ inches, which is consequently one dimension of each of the longitudinal flues. Their other dimension is the depth of three bricks, or nearly 9 inches, with the exception of the middle flue, which is four bricks, or nearly 12 inches.

Mr. Clift states that he worked twelve benches of these brick retorts from 1842 to 1849, when they were taken down for an alteration of the works, and were found then in good condition, and with slight repairs were fit for working several years. He also put up twelve sets in 1844, which continue in regular work to this time. The cost of repairs to the ovens, retorts, and furnaces during these eight years Mr. Clift says has not exceeded 20*s*. per annum for each bench.

The inventor contends that these brick retorts are free from many of the objections which apply to fire-clay retorts made in one piece. He finds that when the temperature of his brick retorts is suddenly altered, either by the carelessness of stokers or in letting down the heat, the great number of joints, each contracting a little, prevent any of that cracking so usual in fire-clay retorts. Also, in getting up the heat, he finds the great number of joints divide the expansion amongst them.

Mr. Clift observes, when a set of these retorts is first put to work, either when new or after being let down for any purpose, they leak through the joints for about twenty-four hours, but this gradually stops, and after that time, if the

heat be good, the retorts will have become quite sound and permanently gas-tight under a pressure equal to 10 or 12 inches head of water.

The inventor estimates the production of one bench of his retorts at 20,000 feet of gas in twenty-four hours, and makes a comparison of the cost of his system with iron retorts set five in a bench, and capable of producing the same quantity of gas. He takes the duration of the iron retorts at a year and a half. The comparison stands thus:

First cost of 20 Benches of Iron Retorts.

Bricks, clay, and labour, for arches	£367	0	0
100 cast-iron retorts, 18 cwt. each, equal 90 tons, at £6 .	540	0	0
Fire-bricks, shields, quarries, &c., for setting . . .	150	0	0
Labour for setting, £3 per bench	60	0	0
	1117	0	0

Cost of renewing 20 Benches of Iron Retorts.

100 iron retorts weighing 90 tons, at £6 .				£540	0	0				
Bricks and clay				150	0	0				
Labour, taking down and re-setting . .				80	0	0				
				770	0	0				
Less by old iron of retorts, 50 tons, at 25*s*.	£62	10	0							
Less by one-third of bricks, which may be used again .	50	0	0	112	10	0				
				657	10	0				
This sum will be multiplied by 6½, the number of times they will be renewed in 10 years, which will give . .								4273	15	0
Total expense of iron retorts in 10 years .								£5390	15	0

First cost of 20 Benches of Brick Retorts.

Bricks, clay, and labour, for arches	£367	0	0
Iron for front plates and back stays, 21 tons, at £6 . .	126	0	0
Pattern and other bricks, and clay for retorts . . .	180	0	0
Labour for building retorts	110	0	0
	£783	0	0

Brought forward		£783 0 0
Cost of repairs for 10 years, at 20*s*. per bench per annnm	£100 0 0	
Less value of old front plates, &c., 20 tons, at 25*s*.	25 0 0	
		75 0 0
Total expense of brick retorts in 10 years		£858 0 0

Mr. Clift having assumed that each bench of retorts will make 20,000 cubic feet of gas per day, he arrives at 1460 million feet as the quantity made by each in ten years, whence he deduces the cost per 10,000 feet at 9*d*. for the iron retorts, and $1\frac{1}{3}$*d*. for brick retorts, showing an economy of 84 per cent. in favour of the wear and tear of brick retorts. It must be observed that both the preceding estimates of wear and tear are remarkably small; Mr. Barlow, Mr. Clegg, and other gas engineers, having usually estimated the wear and tear of iron retorts at something more than $2\frac{1}{2}$*d*. per 1000 feet, or considerably more than double Mr. Clift's estimate; while Mr. Croll, emphatically the champion of cheap gas, has himself in his Evidence stated the wear and tear of brick and iron retorts combined at 2*d*. per 1000 feet of gas.

Brick retorts are extensively used at Birmingham, Nottingham, Lincoln, and some others of the Midland towns, where their performance is said to be highly satisfactory.

WROUGHT-IRON RETORTS.

Besides the forms of retorts which have been mentioned, there is one invented by Mr. King, of Liverpool, which claims a brief notice. This is the wrought-iron retort made about $5\frac{1}{2}$ feet wide by 6 feet long, 18 inches high at the crown of the arch, and 12 inches at the springing, carbonizing nearly 7 cwt. of coal at a charge, or 1 ton in twenty-four hours. These retorts, which were the first introduced in America, are made of thick boiler plate firmly riveted together, with the bottom of the same material, set in an arch of brick-work, heated by one

fire, the bottom being guarded with fire-tiles to protect it from the direct action of the flame, with longitudinal flues under it: the draught passing over the top of the oven makes its exit in the crown near the front. Ovens of this description with cast-iron bottoms are in use in Liverpool.

The shape of these ovens is such as to present a large heating surface in proportion to the mass of coal which they require. Hence, with high heats they present considerable advantages, chiefly in reference to their large production of gas; but at the same time the high heats which they require soon wear out the bottom or put the retorts out of shape. They have not been much used except in Liverpool.

CHAPTER VIII.

MR. CROLL'S METHOD OF SETTING CLAY AND IRON RETORTS TOGETHER.

This is a well-contrived arrangement, combining the two kinds of retorts in such a way that the clay retorts, which require by far the most heat, owing to their greater thickness and inferior conducting powers, should be exposed to the greatest intensity, while the iron retorts receive their heat from a system of return flues, or in a separate oven, in which the heat is not so considerable. Greater durability of the retorts, and a much greater efficiency in production, are claimed for this mode of setting.

The clay retorts used by Mr. Croll are from 18 feet to 20 feet long, made in four pieces, jointed with fire-clay. In his larger works they are set six or seven in a bench arranged round the inner periphery of the oven in a circular form, and

well secured to each other and to the roof of the oven by lumps of fire-brick.

In the large works of the Central Gas Consumers' Company, at Bow Common, which is the last of Mr. Croll's works and therefore exhibits his latest improvements, the furnace is placed at each end of the retorts, so that the elevation of both ends of the bench is precisely the same. A cross-wall extends throughout the whole length of the range of retorts, separating the heated air of one furnace from that of the other, and forming two separate ovens for each bench of clay retorts. Each of these ovens has two elliptical openings about 14 inches by 10 inches through the arch which separates the clay retorts from the iron. These openings admit the heated air from the clay retorts into the oven in which the iron retorts are placed, and the air after circulating through the latter and parting with its remaining heat passes off into a longitudinal flue placed underneath, and communicating with the main shaft.

In other settings where Mr. Croll has used clay retorts of 7 or 8 feet in length, the same general principle is adopted. Only one furnace, however, is required to each bench, and the back of the bench or the closed end of the clay retorts is here the end at which the iron retorts are charged.

In the former case, where the long retorts are used, the iron retorts are cast in one piece the full length of 18 or 20 feet, according to the width of the bench. They have lids at each end, but a mouth-piece and socket-pipe at one end only, as the gas passes off to the hydraulic main only from one end. Sometimes in using short retorts (see figs. 35 and 36) the large longitudinal flue described in the last mode of setting is not used, but in place of it there is a 14-inch transverse flue under the lower iron retort in each oven, which passes from the back to the front of the bench and carries the heated air to a vertical flue which communicates with the main shaft.

In smaller works this mode of setting is somewhat modified, as shown in figs. 33 and 34, which exhibit Mr. Croll's mode of setting at Winchester Gas-Works. In this bench there are

Fig. 34.

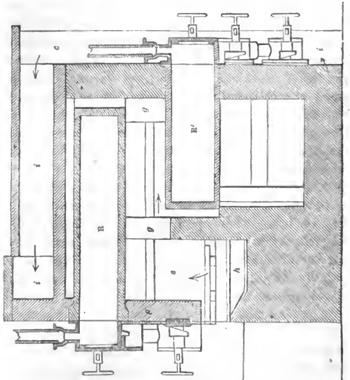
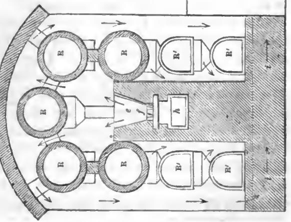


Fig. 33.



five clay retorts, each 7 feet 6 inches long, marked R R, in figures 33 and 34, and four small iron retorts of the same

Fig. 36.

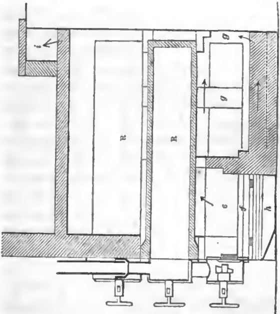
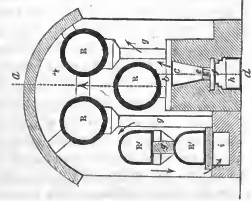


Fig. 35.



length, besides one iron D, 5 feet long, 20 inches wide, and 20 inches high, marked R′ in fig. 34. The entire width of the bench is only 9 feet, and yet in this space are set ten retorts, of which five have their mouth-pieces on one side and five on the other. There is only one hydraulic main, the gas passing over

from one side of the bench to the other on which the main is placed. It will be observed, on reference to figs. 33 and 34, that in this setting there is no arch to separate the iron retorts from the clay, but the setting is so arranged that the heat does not reach the iron retorts till after it has circulated amongst the clay retorts which occupy the part of the oven immediately above the furnace. On reference to the section fig. 33, it will be seen that there is a solid partition of fire-brick between the clay retorts to prevent the heat passing through until it strikes the top of the oven, when it passes round the upper retorts and down the sides of the oven to heat the iron retorts. This being effected, the heated air passes along a longitudinal flue under the iron retorts and through an ascending flue (*c*, fig. 34) at the front of the retorts, as indicated by the arrows.

Figs. 35 and 36 show another form of setting from Mr. Croll's designs, also at Winchester. In this bench are three circular clay retorts, and two iron D's, all $7\frac{1}{2}$ feet long.

Figs. 37 and 38 show another combination of clay and iron retorts set up in several of the benches at Winchester by Mr. Pontifex, who highly approves of Mr. Croll's mode of heating iron and clay retorts by the same fire. Figs. 33 to 38 inclusive are all drawn on a scale of $\frac{1}{48}$th the full size, or a quarter of an inch to 1 foot. Fig. 33 is a cross section, and fig. 34 a longitudinal section through the centre of fig. 33. Fig. 35 is a cross section, and fig. 36 is a longitudinal section in the line *a b c d* in fig. 35. Fig. 37 is a cross section, and fig. 38 is a longitudinal section through the centre of fig. 37. The following letters represent similar parts in all these figures: R R R, &c. are the clay retorts; R′, &c. are the iron retorts; *e* is the furnace; *f* the fire-bars; *g* the fire-brick walls supporting the retorts; *h* the ash-pit; and *i* the flues. The arrows indicate the direction of the heated air, which is made to circulate round the clay retorts before coming in contact with the iron ones. In all these modes of setting, the object is to apply the most intense heat to the clay retorts, and

Fig. 38.

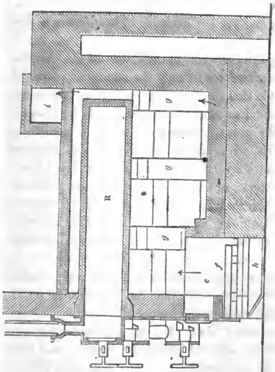
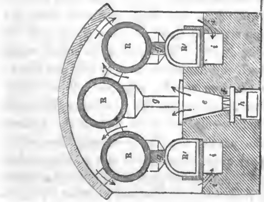


Fig. 37.

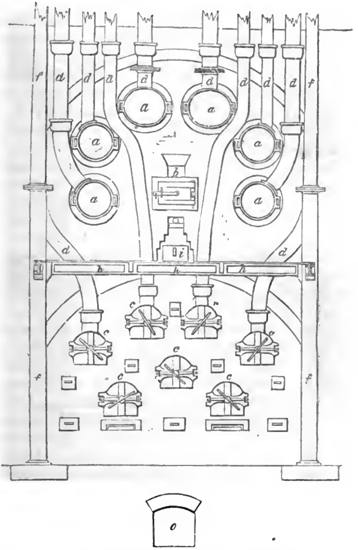


afterwards to use it, when somewhat diminished in intensity, for the lower or iron retorts. In these various examples will be observed the same contracted furnace and minimum quantity

of fire-grate which distinguish Mr. Croll's Works at Bow Common, and yet the evidence is unanimous in favour of the sufficient heating power.

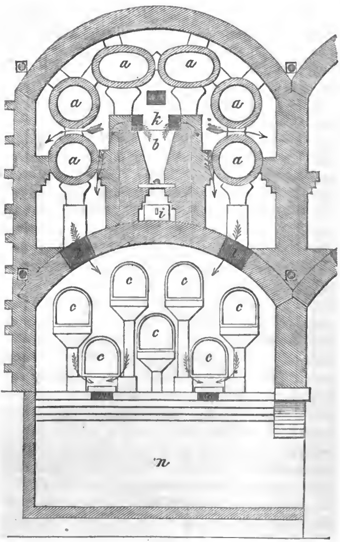
Through the courtesy of the Editor of the 'Artizan,' who has kindly permitted me to copy the admirable plates of this work published in that Journal, I am enabled to give in figs. 39 to 42 a longitudinal section, an elevation, and cross section of one of Mr. Croll's ovens, showing the mode of combining iron and clay retorts, as practised by him on the very largest scale. These figures are all on a scale of 1 inch to 4 feet: *a a a* are the clay retorts, of which the upper two are elliptical, 16 inches by 12 inches, and the other four circular, 15 inches in diameter inside. Each clay retort is made in four pieces, which are jointed together with fire-clay, as described elsewhere. *b b* are the furnaces at each end of the retorts, which are ranged so as to receive an equal share of the heat which radiates in the upper oven: *c c c c*, &c. are the iron retorts set in the lower oven, which receives the heated air through the openings *l l* in the lower arch: *d d d*, &c. are the ascending pipes, which pass up from each end of the clay retorts, and from one end only of the iron retorts. In the engraving from which our wood-cuts are taken only eight ascension pipes are shown; but this is an error, as there are nine at one end of the oven, and ten at the other. This latter is the actual setting at Bow Common, each end having alternately four and three ascension pipes from the iron retorts, together with six from the clay retorts. Our wood-cut, fig. 39, represents this arrangement: *f f* are the hollow columns which support the hydraulic main. These columns are tied together by wrought-iron rods extending over the upper oven. Projections cast on these columns carry the girders *h h*, and these girders support the cast-iron floor or platform from which the retorts are fired: *i i* are wrought-iron troughs supplied with water, the evaporation of which serves to keep the fire-bars cool; *j* is the partition-wall between the two furnaces; *k k* are the walls which carry the retorts, and which are perforated with holes to allow the

Fig. 39.



heated air to pass through: $l\,l$ are the openings 14 inches by 10 inches, and four in number in each arch, to admit the heated air from the upper to the lower oven: $m\,m$ are the

Fig. 40.



openings from the lower oven into the horizontal flues *n n*, which extend along the whole range of retorts, and open into the main flue leading to the chimney: *o o* are flue-doors for cleaning out the horizontal flues, and the openings *m m* are also

provided with fire-tile dampers to adjust the draught. It is scarcely necessary to describe that fig. 39 is a front elevation of one bench of retorts. Fig. 40 is a transverse section parallel to the face, and figs. 41 and 42 being joined together at the line *x*, which is the top of the lower arch and is common to both figures, will form a longitudinal section at right angles to the face of the bench.

It will be observed from the description we have given of the different modes of setting, that independently of the use of clay retorts in combination with iron, and the consequent change in the mode of conducting the heat, Mr. Croll's system presents an important variation from the older method.

According to the method first described, and which is far more extensively practised than any other in the Metropolitan Gas-Works, the heat passes through openings in the *side* of the furnace, acts first on the bottom of the retorts, then passes up at the sides, circulates amongst them, and escapes through openings in the arch of the oven into a longitudinal flue at the top and over the arch. Now Mr. Croll's plan is entirely different: his furnace is open instead of being arched over, and the heat is allowed to escape from the top and diffuse itself at once, instead of being confined and allowed to act with great intensity on the bottom of the lowest retorts. This diffused mode of applying the heat is found sufficient even for the clay retorts. Then, when the heat is somewhat diminished in fierceness, it is conducted into the oven of the iron retorts and allowed to exert its action on them: the heat is still acting, therefore, in the retorts instead of escaping through the arch of the upper retort-oven, which in Mr. Croll's plan is close, and contains no openings whatever.

The merits of these opposite methods of applying heat have, perhaps, not been sufficiently tested; at all events, they have not been so tested as to induce uniformity of opinion on both sides of the question; but we may shortly expect, from the present watchfulness of all parties concerned, and that spirit of emulation which always attends severe competition, to have such

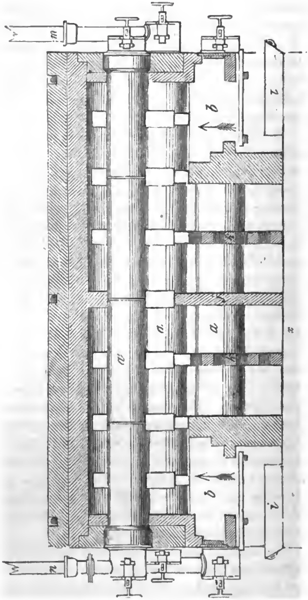


Fig. 41.

data produced as will furnish a secure guide for future operations. In the mean time the accounts given of the working at

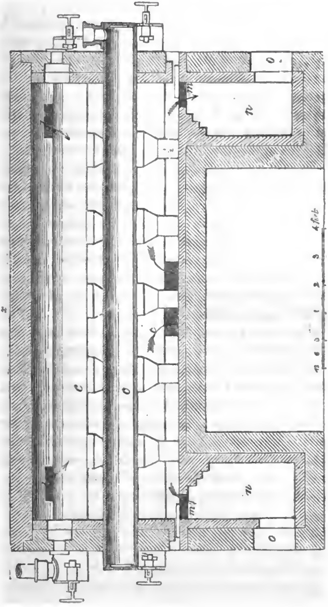


Fig. 42.

Bow Common are highly favourable. The production of gas is said to exceed 9500 cubic feet per ton, and the carbonization

is said to be carried on with an expenditure of only 12 per cent. of fuel,—that is to say, 100 tons of coal are carbonized by 12 tons of coke. If this result be maintained, it will go far to prove the superiority of Mr. Croll's mode of setting, and to carry out the truth of his principle, that clay retorts and iron retorts require different intensities of heat, and in consequence should never be set in the same oven, but in separate ovens, the spent heat of one being afterwards used for the other. Of course in small works where the operations are very limited, it may not always answer to incur the expense of two separate ovens for each bench of retorts, and hence the modifications adopted at Winchester and other small works, where return flues are introduced instead of having two separate ovens. These, however, are only exceptions to Mr. Croll's general principle, and carry out somewhat imperfectly that which he professes to effect in the most complete manner by the separate arched ovens for each class of retorts, as adopted in his large Metropolitan works.

Most of the large London Gas Companies have either commenced the use of clay retorts, or have made arrangements for doing so. The City of London, the Phœnix, and the Chartered Gas Companies have already adopted them to a considerable extent, and the Imperial Company, which at present uses York D's from $7\frac{1}{2}$ to 9 feet long, is about to erect 300 clay retorts. Most of the trials at present made have been confined to the short retorts. The Phœnix Company, however, is using clay retorts of double the usual length, and charging them at both ends as already described.

CHAPTER IX.

ON THE MODE OF WORKING RETORTS.

The fuel commonly used for heating the furnaces is the coke made in the retorts. The quantity of coke required for fuel of course varies very much with the quality of coal. Where Newcastle coal is used, the carbonization is seldom effected with less than 25 per cent. or one-quarter of the coal, that is to say, a ton of coal requires to carbonize it nearly 5 cwt. of coke. Coal is usually spoken of by weight, and coke by measure. The Newcastle coal generally yields about one chaldron of 36 bushels for every ton of coal, or from 13 to 15 cwt. of coke. In London, about one-third of the coke made is used for carbonizing in the furnaces, the surplus two-thirds remaining for sale, as more particularly described in the section devoted to residual products.

In setting iron retorts, those which are lowest in the oven, and consequently most exposed to the heat of the furnace, are usually set on fire-tiles an inch and a half in thickness, and the sides are also frequently protected in the same way. The upper retorts do not require the protection of fire-tiles, which are also unnecessary for clay retorts and for the iron retorts set in a lower oven on Mr. Croll's plan.

The usual charge for the small iron D retorts is from 120 to 170 lbs., and the time of charging from six to eight hours; the six-hour charges being decidedly better, especially as regards the quality of the gas, which deteriorates very much during the last period, and at length consists of very little more than hydrogen gas, with the most feeble illuminatiag power. In preparing a bench of retorts and bringing them into working order, the furnaces should be lighted some time before, and the retorts brought up to a good working heat before any coal is introduced. In iron retorts, a cherry-red heat is found suffi-

cient, but clay retorts will bear without injury a white heat, or at all events an orange-red heat.

In small works where only one or two men are employed to work the retorts, the charge is thrown in with a common shovel, the lid of the retort being kept off all the time of charging, which occupies from 20 to 40 minutes, according to the size of the retort and the amount of charge. During the greater part of this time there is a considerable escape of the gas and the very earliest products of combustion, in addition to the loss of time occupied in throwing in the charge. In order to remedy these inconveniences, a method has been contrived for depositing the whole charge in the retort at once: for this purpose an iron scoop is used, this being a semi-cylinder of sheet iron from 7 to 9 feet long and 10 or 12 inches diameter, with a cross handle at the end to assist in lifting it and turning it round to empty the coals in the retort.

The charge of coal is placed in the scoop while it rests on the ground or on two small iron supports: one man takes hold of the cross handle, and two others lift the other end and introduce it into the mouth of the retort. The scoop with its contents is then pushed forward to the further end, turned completely over, and immediately withdrawn, when the coal left in the retort is, at some works, raked into a stratum of uniform thickness, and the lid, previously luted and ready, is jointed on as quickly as possible. The operation of charging with the scoop does not occupy more than 30 or 40 seconds, so that very little escape of gas can take place, and hence the scoop has come generally into use where-ever the works are large enough to supply three men for the purpose of lifting it. Before drawing the charge it is customary at some works to loosen the lids of the retorts and apply a light to the gas which escapes, beginning with the upper retorts. For want of this precaution, many lamentable accidents have happened through the gas taking fire when so combined with atmospheric air as to form an explosive compound.

In most of the London Works where the retorts are set back

to back, or where retorts of double length are used, it is usual to work each face with at least three stokers and an extra man for preparing the lids of the mouth-pieces, another for extinguishing the coke, and men for wheeling the coal into the retort-house ready for being placed in the scoop. Three stokers, assisted by a man to extinguish the coke, will perform all the work of taking off the lids, raking out the coke, extinguishing it, and wheeling it away from a bench of seven retorts, in 12 or 13 minutes: they will then put the proper charge for each retort in the scoop, deliver its contents, and be ready for charging another bench in a further space of 7 minutes, while a fourth workman will in the mean time have put on the lids, so that the whole work of emptying and recharging the seven retorts will occupy barely 20 minutes.

This extreme dexterity is of course only acquired by long practice, and it must be admitted the labour is very severe. The first process is for two or three of the men each to relieve the screw of the mouth-piece by giving three or four rapid turns; another man instantly gives a knock to each of the cross bars to disengage them from the ears of the lid, and at the same time gives the lid a blow with a piece of iron or hammer in order to break the luting. The men then lift off the cross bar and screw of each retort, placing them on the ground, and then each seizes hold of a lid in both hands, lifting it by the projecting ears and carrying it a little on one side, where it is thrown down on the ground: in the mean time the workmen have dexterously to avoid the great sheets of flame which are now issuing from the retort, accompanied by slight explosions which take place as soon as the gas catches fire. Three of the stokers then take up their iron rakes, which are simply rods of three-quarter inch iron, 12 feet long, with one end turned at right angles and flattened. These are inserted in the retorts, and the red-hot coke drawn to the mouth, whence it drops either into the coke-vault or into iron barrows placed ready to receive it.

Mr. Croll uses light sheet-iron waggons on four wheels, with

covers which open sideways and slope backwards to the front of the bench, so as to form an inclined plane and prevent the coke dropping down in front. A labourer should be employed in throwing cold water on the coke as soon as it comes out, the heat being very intense. The coke is then rapidly wheeled off, and if any has been spilled it is taken up on an iron wire shovel and placed on a barrow. Three large iron barrows will contain the coke from seven iron retorts 7 or 8 feet in length. Where the iron waggons are used, the sloping cover prevents any of the coke from being spilled. The charging now begins as follows: The scoop is laid on the ground, and two or three men very quickly place in it as many shovels-full of coal as will make up the charge: then two of them insert a bent bar of iron under one end of the scoop, while the third takes hold of the cross handle at the end; the weight divided amongst three is easy to lift, and the scoop being placed within the retort is immediately pushed up as far as it will go, and turned quickly over: in an instant the fourth man approaches with his lid already luted all round with a breadth of 1½ inch of the composition, about ¾ of an inch thick, and fixes it on in its proper place; he then stoops down, picks up the cross-bar and the screw which passes through it, fixes the former in the two ears of the mouth-piece, and immediately tightens the lid by turning the screw and causing it to press on the back of the lid. All these operations in a well-conducted establishment are performed with an accuracy and dexterity which is worthy of much admiration, considering the dreadful temperature in which the poor fellows have to work. The composition for luting the retorts is made of the spent lime from the purifiers, mixed with a little fire-clay, and well worked up with water like mortar. In large works it is prepared outside the retort-house and brought in by wheel-barrows as required. In dressing the retort lid with the luting, the workman uses a trowel, and works a little of it up on a board, and applies it all round the rim as already described.

In works which are situated near a railway it is of course highly desirable to effect as intimate a connection with the rails

as possible. Mr. Croll has a railway at Bow Common laid from his works to the canal which communicates with the river Lea and with the coal dépôt at the mouth of that river. A line of rails is actually brought into the retort-house, and laid along each side of the retort-benches.

The rails are stout castings in the fish-bellied form, with iron supports every 10 feet; the surface of rails is about 4 feet above the charging floor of his upper ovens, and the coal is simply discharged out of the waggons on the floor. The entire absence of sleepers and of all obstructions, except the pillars 10 feet apart, gives every facility for using the coal whenever required. By this contrivance all expense of wheeling coal is saved.

Mr. Croll causes the red-hot coke, as it comes from the furnaces, to be conveyed in wrought-iron barrows or waggons to the furnaces which require feeding, and effects in this way a considerable saving of fuel. This method is also practised at the Chartered Gas-Works, and by other companies.

Two workmen at least are necessary to work a retort; whilst one is preparing a new lid, the other is breaking the coal and making ready the charge to be placed in the retort.

The French use an iron barrow for the hot coke, with the body in the shape of a semi-cylinder, which can be turned round by means of a handle and made to discharge its contents with great readiness. This contrivance is of course only necessary where the works are unprovided with a coke-vault, because where a vault exists, the coke would at once fall through into it on being raked from the retorts.

It is usual to extinguish the incandescence of the coke by throwing water upon it.

In small works, when the lid has been de-luted and the coke raked out, two workmen proceed to throw in the charge with a shovel; while near the end of the charging, one of them stands ready having the lid prepared with a rim of luting, and as soon as the charge is placed in, he proceeds to fix the lid, and to tighten it by means of the screw. In larger works, where the

scoop is used for charging, three men are required, as already explained, to use the scoop. In small establishments two stokers are generally sufficient to work two benches of D retorts, or at the rate of one man to five retorts; but in large works the proportion of workmen is not nearly so great. Mr. Barlow estimates thirty stokers by night and thirty by day for the work of 400 retorts, giving an average of more than thirteen retorts to each.

TEMPERATURE OF FURNACES.

With reference to the heat which it is proper to employ in the distillation of coal for gas-making, it is unfortunate that science has not yet furnished the practical man with any convenient method of estimating high temperatures. Wedgewood's pyrometer, though extremely ingenious, gives all its indications on so small a base line as to require an accuracy and homogeneity in the composition of the clay cylinders employed which is physically impossible. The range of temperature indicated by the Wedgewood pyrometer being more than ten times greater than the range from the freezing to the boiling point of water, has to be expressed within the limits of only $\frac{2}{5}$ths of an inch, this being the extent to which a cylinder of clay contracts between a faint red heat at about 950° Fahrenheit and the melting point of cast iron at 2800° Fahrenheit. It is true this very small range of $\frac{2}{5}$ths of an inch, divided as it is into 240 parts, is made appreciable by Wedgewood's contrivance of reading off on a base or ruler about 2 feet long, but the delicacy of observing and manipulating with such an instrument is too great to render it available for practical purposes, besides which the cones or cylinders of clay can never be procured sufficiently uniform in structure.

Daniell's pyrometer is, perhaps, superior to any other that has been tried. Its indications are caused by the expansion or contraction of a bar of platinum connected with a lever which acts as an index. The dial on which the index revolves affords room for a greatly increased space to read off the

results, but this instrument for practical use is liable to some of the objections against Wedgewood's pyrometer. The recent methods pointed out by Mr. Prinsep for determining high temperatures by means of fusing the metals and their alloys, is far too troublesome and complicated for practical use. The beautiful experiment of obtaining the temperature of a furnace by means of thermo-electric currents is also far too delicate for ordinary use, and until some contrivance more capable of being reduced to daily practice shall be introduced into gas-making, we must be content to be guided in a great measure by the colours presented by the interior of the furnace. Constant observation will, indeed, greatly improve the faculty of estimating high heats by the shades of colour which they present, and at all events enable the observer to compare and adjust the working of his furnaces. The following Table of high temperatures, expressed in the colours commonly used, with their corresponding temperatures reduced to Fahrenheit's scale, has been principally compiled from M. Becquerel's 'Traité de Physique.'

Faint red	960°	Fahr.
Dull red	1290	"
Brilliant red (colour of red oxide of lead) .	1470	"
Cherry red	1650	"
Bright cherry red	1830	"
Dull orange	2010	"
Bright orange	2190	"
White heat	2370	"
Bright white	2550	"
Brilliant white	2730	"
Melting point of cast iron	2786	"
Greatest heat of iron blast-furnace . .	3300	"

The heats considered most advisable for iron retorts are cherry red and bright cherry red, ranging from 1650° to 1830°. It is found that higher temperatures than this, although they produce more gas, are very destructive to the retorts. For clay retorts, however, the bright orange merging into a white heat may be used with advantage.

CHAPTER X.

THE HYDRAULIC MAIN AND ITS PIPES FOR CONNECTING THE RETORTS WITH THE MAIN.

THE pipes leading from the retort to the hydraulic main are not fitted into the retort itself, but into a separate casting termed the mouth-piece, which is commonly of the same size as the mouth of the retort, and is secured to it by a flange and bolts, as before described when speaking of iron retorts. The same kind of mouth-piece is used for clay retorts, which, instead of a flange for attaching the mouth-piece, are provided with a ring, 4 inches in thickness and 6 inches in breadth, through which holes are cut to receive the bolts for securing the mouth-piece.

A bent pipe passes up from the mouth-piece to the hydraulic main, the straight part secured to the mouth-piece being called the stand-pipe, while the other straight part passing into the hydraulic main is called the dip-pipe. The part connecting the dip and stand pipe is called the bridge-pipe, and this part is usually provided with two bonnets, which can be removed when the pipes require cleaning. The stand and dip pipes vary in diameter from 3 to 6 inches, a very usual size being 4 inches. There are various modifications in the arrangement of pipes between the retorts and the hydraulic main. In England the stand-pipe usually passes up to a height of four or five feet above the main, and is fitted at the top with a semicircular bridge-pipe, which connects it with the dip-pipe.

s s, in figs. 24 and 25, show the form of the pipes used at the Philadelphia Works, where the bridge-pipe is somewhat different from that generally used in England. Another arrangement has been employed at some of the gas-works in

France, where the stand-pipe passes through the hydraulic main, and is covered by a dip-pipe which allows the gas to pass down in the annular space surrounding the stand-pipe into the tar of the hydraulic main. In all these contrivances the main is placed above the retorts; but this is not absolutely essential, as it has frequently been placed with advantage beneath the firing floor.

THE HYDRAULIC MAIN.

This is a tube or trunk,—usually, but not always, of cast iron,—extending the entire length of the retort-house, and varying from 12 to 18 inches diameter, and generally $\frac{5}{8}$ths to $\frac{3}{4}$ths of an inch in thickness when made of cast iron. Wrought-iron hydraulic mains, however, are now beginning to be used, and will probably altogether supersede cast-iron, on account of their lightness and strength. These are usually made of larger diameter than the cast-iron, and put together in longer lengths. See figs. 43 to 45 for the details of the wrought-iron hydraulic main just erected by Messrs. Cowley and Co. for the Phœnix Gas Company.

The main is made of $\frac{3}{8}$-inch boiler-plate. The ring forming the main is composed of two circular plates and one flat piece on the top, as shown in fig. 43. The circular plates are made of two breadths, namely, about 3 feet and 2 feet, and about 5 feet 6 inches in length. They break joint with each other, by having their line of division alternately on opposite sides of the main. (See fig. 43.)

The main is constructed in lengths of 23 feet, and at each end of this length there is a flange 3 inches wide, shown in elevation in fig. 44, which also shows the bolt-holes through which the bolts pass for securing the separate lengths of main. At the end of each length, and also midway in each length, is a division-plate, 7 inches deep in the centre, shown in fig. 43. A plan or top view of one length of main is shown in fig. 45, which exhibits the mode in which the end flange is attached to

Fig. 43.

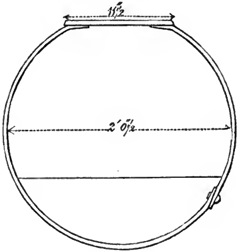
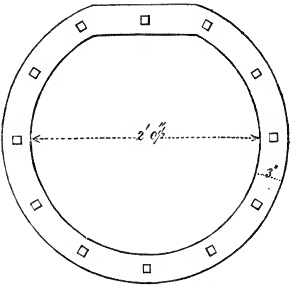
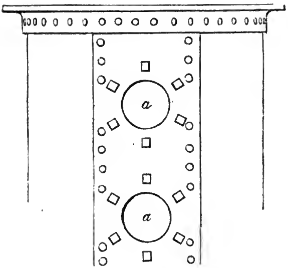


Fig. 44.



the main. This flange consists of 3-inch angle iron, half an inch thick, bent into a circular form, one side being secured to the

Fig. 45.



main by $\frac{3}{4}$-inch rivets, $1\frac{3}{4}$ inch apart all round. The bolt-holes in the face of the flange, shown in fig. 44, are $\frac{3}{4}$ inch square. The flat top plate is in lengths, of which three correspond to one 23-feet length of main; each length takes seven dip-pipes. Two of the openings to receive the ends of the dip-pipes are shown at *a a*, fig. 45. These openings are $5\frac{1}{4}$ inches diameter, and 12 inches apart from centre to centre. Each opening is surrounded by six bolt-holes, $\frac{7}{8}$ square, to receive the bolts for fastening the flanges of the dip-pipes. Figs. 43 to 45 are drawn on a scale of $\frac{1}{12}$th, or 1 inch to a foot. The cost of the main erected complete is £17 per ton.

The cast-iron mains are generally of such a length as to reach over two benches, and the joints are made with bolts and nuts, and iron cement, in the usual manner. In old works the hydraulic main is usually a circular tube, but of late years D-shaped mains have frequently been used, generally with the flat side downwards. Mr. Croll, however, at Bow Common has a D-shaped main with the convex side downwards.

The hydraulic main when first brought into action is filled about half-full with water, but the tar contained in the gas which passes into it is soon deposited in the hydraulic main, so that the sealing liquid changes its character and becomes nearly all tar.

The hydraulic main being filled about half-full with water, the end of the dip-pipe passes through the water to a depth of 3 or 4 inches. The gas from the retorts then passes down the dip-pipe and bubbles up through the water till it arrives in that part of the main above the surface of the liquid. The hydraulic main, therefore, is the first receptacle in which the gas is collected after its separation from the coal.

Allow me for a moment to dwell on the beautiful ingenuity exhibited in the hydraulic main, with its contrivance of a dense fluid for the purpose of forming a perfectly air-tight and gas-tight chamber, and cutting off all communication from this chamber to the retorts, while the passage of gas from the retorts to the chamber is perfectly free and open. This condition will be apparent if we consider for a moment that the extreme lightness of the gas will always cause it to pass upwards through the tar, while, once arrived over its surface, it has no power whatever to displace the tar and pass backwards. The hydraulic main constitutes the first application in the gas manufacture of that beautiful contrivance called the water-joint. It is this contrivance which enables the chemist to store and confine his gases in the receivers of the pneumatic trough, and thus by the use of denser fluids, such as water and mercury, to imprison the most volatile forms of gaseous matter in a mode which, for delicacy and subtilty, infinitely excels every contrivance of mere mechanical fitting. We shall see hereafter how largely this valuable principle of sealing up the aëriform fluids by means of denser fluids, through which they can pass in one direction but not in the other, has been applied in the purifier, the gas-holder, and, in fact, in every one of the contrivances connected with the collection, storing, and distribution

of gas. At present it may be sufficient to point attention to the value of this property derived from the different densities of fluids, which gives both to the chemist and the manufacturer a power over the aëriform bodies which they would strive in vain to obtain by any other means.

Each of the pipes thus dipping into the tar of the hydraulic main freely delivers the gas produced in its own retort, and effectually prevents its return. However numerous may be the pipes dipping into the hydraulic main, whether they contain gas or not, and whether the retorts are working or not, it is impossible that any gas once arrived above the surface of tar in the main can escape back again by any of the pipes. Each open end is hermetically sealed against the return of gas which has once been delivered into the main.

The length of the dip-pipes should not be less than 3 feet, and is frequently made as much as 5 feet, in order to prevent the tar rising in the dip-pipes connected with the empty retorts as high as the bridge-piece. It is obvious that the pressure of gas from the working retorts will force the tar up a short distance into the empty dip-pipes, but this distance is seldom if ever equal to 3 feet. As the hydraulic main is generally half-full of tar, its diameter must be so regulated that the tar forced up into the empty dip-pipes will not so far diminish the depth in the main as to uncover the ends of the dip-pipes, because this would simultaneously unseal every one of them, and the gas would immediately escape from the main.

The hydraulic main is sometimes placed on the solid structure of the brick-work over the retorts, but more frequently a little in advance of the ends, in which case it requires to be supported by columns. The hydraulic mains at the Great Central Gas-Works are in the shape of a reversed D, 18 inches wide and 18 inches high. There is one on each side of the stack of retorts. The main is cast in lengths of nearly 10 feet, so as to reach over one bench of retorts, and the joints are placed over the centre of the arches. The thickness of the main is $\frac{5}{8}$ths of an inch with a $2\frac{3}{4}$ flange at

the ends of each length. The upright pillars to support the main are hollow columns 7 inches diameter at base, 6 inches at top, and ⅝ths of an inch in thickness. A pillar is placed in the centre of each length of the main, and the opposite pillars are tied together by bars of inch round iron stretching entirely across the bench of retorts.

Each length of the hydraulic main is usually provided with a partition, the top of which is level with the surface of the fluid, and the object of which is to keep the fluid up to the same height in every part of the main. Of course where so much depends on the effective sealing up of the ends of the dip-pipes, every care must be taken to fix the hydraulic main in a perfectly horizontal position from end to end. When the hydraulic main is of cast iron, the holes to receive the ends of the dip-pipes are cast in it, and the flanges of the dip-pipes are secured to the main by nuts and bolts, the joint being made with the usual iron cement, such as that used for attaching the mouth-pieces to the retorts. Where the main is of wrought iron, as shown in figs. 43 to 45, the top is formed by a flat piece to which the wrought-iron circular part of the main is attached by rivets, and in this flat piece the holes for the dip-pipes are cut by hand. One end of the hydraulic main is closed by a plate having the same section as the outside flange of the main, to which it is bolted and secured by iron cement. A similar plate is also bolted on at the other end of the main, but this plate is provided with an orifice usually about half the diameter of the main itself. The lower part of this orifice is immediately above the level of the fluid in the hydraulic main, and the orifice itself corresponds with the exit-pipe which conveys away the gas to the condenser. The flange of the exit-pipe is bolted on to the perforated end plate of the main. The exit-pipe is usually provided, soon after leaving the hydraulic main, with a descending pipe to carry off the tar into the cistern below the condenser. The lower end of this descending pipe must be sealed either by dipping several feet into the tar of the cistern, or into a small well

which communicates with the cistern. The descending pipe to carry off the tar is not absolutely necessary at this place, because the same office is sometimes performed by the siphon-pipe at the first bottom bend of the condenser; it is often adopted, however, because it is advisable to separate the tar as soon as possible.

CHAPTER XI.

ESTIMATES OF RETORTS.

MR. CLEGG, in his valuable treatise published by Mr. Weale in 1841, has given some minute details of the cost of setting retorts, and of taking down and re-setting them in benches. The amounts of these estimates, however, are of course subject to great fluctuations, as may naturally be expected when we consider that they are wholly composed of two articles, namely, labour and materials, the value of which, but particularly the latter, is constantly varying. Mr. Clegg's estimate for taking down and re-setting a bench of five D retorts, including the arch of the oven, is thus composed:

	£.	s.	d.
Five D retorts, each weighing 13 cwt., at £7. 10s. per ton	24	7	6
Fire-bricks, common bricks, fire-tiles, lime, sand, fire-clay, and cement	9	6	0
Labour	4	9	6
	£38	3	0

Mr. Barlow, the talented editor of the 'Journal of Gas-Lighting,' has gone very fully into the question of retorts, in his Report to the City of London Gas Company on the sub-

ject of the Great Central Gas Consumers' project in 1850. In this Report Mr. Barlow estimates the annual cost of 526 retorts, half of iron and half of clay, at £3891; and from his details the following estimate is drawn as to the cost of a bench of five D retorts, for the purpose of comparison with Mr. Clegg's estimate:

	£.	s.	d.
Five iron retorts, each weighing 16 cwt., at £5 each	25	0	0
Taking down old retorts, breaking the connections, and removing old materials; five, at 4*s*.	1	0	0
Bricklayers' wages, re-setting five new retorts, at 10*s*. 6*d*.	2	12	6
Clay, fire-bricks, and fire-tiles used in re-setting retorts and in repair of furnaces; five, at 20*s*.	5	0	0
Making good connections to hydraulic main; five, at 3*s*.	0	15	0
Bolts and cement for new connections, wear and tear of ash-pit pans, furnace-doors and bars, ears and cross-bars, barrows, scoops, shovels, brooms, &c.	2	10	0
	36	17	6
Allowance for contingencies and defective retorts, 10 per cent.	3	13	9
	£40	11	3

This estimate is in reality somewhat under Mr. Clegg's, as Mr. Barlow has calculated on retorts weighing 16 cwt. each instead of 13 cwt. It is probable, that at the present low price of iron and labour, contracts would be taken to erect benches of iron D retorts, weighing 16 cwt. each, at £35 per bench, including the arch of the oven; and generally it may be assumed that the wear and tear of iron retorts, supposing them to require renewal every twelve months, will range from £7 to £8 each.

The following is Mr. Croll's estimate for the first erection of 252 single iron retorts and the same number of single

clay retorts, including the connecting pipes and hydraulic main.

Materials.	Weight of each. cwt.	qrs.	lbs.	Total. tons	cwt.	qrs.	lbs.
252 iron retorts and mouth-pieces	16	3	0	211	1	0	0
252 mouth-pieces to clay retorts	1	3	20	24	1	0	0
504 ascension-pipes, 4 inches diameter, average length 20 feet	3	3	0	94	10	0	0
72 lengths of hydraulic mains	12	0	0	43	4	0	0
900 retort lids	0	1	22	20	1	3	4
Iron joints of raised retort-stage, three to each oven; 32 ovens, 5 inches deep; and flange, 2 inches broad and 1 inch thick	1	3	0	9	9	0	0
Open floor-plates of retorts, raised stage covering 355½ feet by 3 feet, at 28 lbs. to a foot	..	..	..	13	6	2	14
Pillars to support hydraulic main, 76½	2	0	14	8	2	2	7
Retort binders, two at each, and in all 8	10	0	0	4	0	0	0
36 furnace door-frames	0	3	8	1	9	2	8
36 ashpit-pans	1	1	20	2	11	1	20
360 retort sight-stoppers	0	0	15	2	8	0	24
				434	5	0	21

tons cwt. qrs. lbs.	£.	s.	d.
434 5 0 21 at £10 per ton	4345	0	0
Brick-work in division-wall, raised stage, arches, &c., 62⅜ rods, at £11	697	13	4
Concrete in foundations of retorts, 640 cubic yards, at 6s.	192	0	0
6000 fire-bricks to each setting, each setting 8 feet 6 inches wide, by 14 feet high and 9 feet deep, 9-inch work, 1400, and 160 of the above to set the iron retorts included in the above 6000; 216,000, at £4. 4s. per 1000	907	4	0
252 earthen retorts, at £3. 10s. each	882	0	0
92¼ tons of fire-clay, at £1 per ton	92	5	0
Workmanship of fire-brick portion of retorts	360	0	0
	£7476	2	4

This is at the rate of nearly £15 for each retort.

Mr. Clegg says, 250 retorts set in ovens, five in each oven, and each retort capable of carbonizing 6 cwt. of coal in twenty-four hours, including hydraulic main, dip-pipes, and brick-work complete, will cost £5000, or £20 for each retort and its appurtenances.

Mr. Barlow's estimate is £17. 15*s*. for each retort set complete, including, as before, the hydraulic main and all appurtenances.

Some gas engineers prefer to estimate the duration of retorts by the quantity of gas produced, and this certainly is a more direct and practical measure of their duration than mere time, because they may not have been employed during the whole period over which the duration is extended. Supposing an iron D retort to be in constant use, carbonizing daily four charges of coal of 140 lbs. each, this will amount to $\frac{1}{4}$th of a ton every 24 hours, from which, at the rate of 9000 feet per ton, 2250 feet of gas will be made every 24 hours,—or in the course of 365 days, 821,250 cube feet. Mr. Croll and Mr. Barlow appear to have agreed, in the discussion on the Central Gas Consumers' Bill, that the duration of iron retorts was equal to the production of 700,000 cubic feet of gas, which would correspond with a period of constant work equal to something less than twelve months. It is presumed from these considerations that no sensible error will arise from assuming the duration equal either to the production of 700,000 cube feet of gas, or equal to twelve months' wear in the ordinary practice of gas-works.

CHAPTER XII.

ON THE RETORT-HOUSE.

In deciding on the dimensions of the retort-house and the number of retorts to be employed, it is important not to estimate their power of carbonizing too highly. Thus, although 9000 cubic feet of gas, and even a larger quantity, is frequently made from a ton of Newcastle coal, it is not safe in arranging the construction of a gas-work to estimate the production at more than 8000 feet per ton. The quantity of gas required to be made in twenty-four hours being known, the quantity of coal to be carbonized will be found in tons by dividing the cubic feet of gas by 8000. Supposing a quantity of gas equal to 240,000 cubic feet to be required in twenty-four hours, it is evident, according to the preceding rule, that provision must be made for carbonizing 30 tons of coal in twenty-four hours.

The carbonizing power of the large or York D retorts is equal to about $2\frac{1}{4}$ cwt. of coal every six hours, or each retort will carbonize 9 cwt. of coal in 24 hours. Hence $\frac{30 \times 20}{9} = 67$ the number of such retorts which will be required for the purpose of carbonizing. Suppose again that the London D retorts are used and charged every six hours with $1\frac{1}{2}$ cwt. of coal, then the work of each retort will be represented by 6 cwt. of coal every 24 hours; hence $\frac{30 \times 20}{6} = 100$ of such retorts required to do the same work as 67 of the York D.

At many of the large London works a smaller sized retort is used, and charged every six hours with 140 lbs. of coal, making its performance equal to 5 cwt. in 24 hours. By repeating the above calculation it will be found that 120 retorts of this description or 24 benches of five each will be required to carbonize the 30 tons of coal in 24 hours. These examples will

render the reader familiar with the mode of arranging the number of retorts, whatever shape or variety may be used, provided always the carbonizing power of each kind of retort be known. Where two or more different kinds of retorts are used in combination, the calculation is equally simple.

In England the retort-house is commonly built in the form of a rectangle, and the benches of retorts placed side by side from one end to the other. The retorts are placed back to back, so that in a retort-house containing 24 benches, 12 of these have the front or open ends towards one side of the retort-house, and the other 12 are turned towards the other side. The space usually occupied by a bench of London D retorts is about 7 feet from centre to centre of pier, and the two retorts placed back to back with a 14-inch partition between them occupy a width of 15 to 18 feet, according to the length of the retorts. Where a coke-vault is built underneath the firing floor, it is advisable, in order to avoid excavation, to have the floor of the coke-vault about level with the surface of the ground. The height from the ground floor to the firing floor may be 8 or $8\frac{1}{2}$ feet, and the firing floor should be supported by arches springing from piers carried up from below the ground line. These piers should correspond with and support the piers alternating with the arches in which the retorts are set. The retort-house is usually made about 14 feet longer than the space occupied by the retort benches, in order to allow plenty of room for passing round the retorts, &c. Thus, supposing 24 benches of retorts set 12 on each side, these will require for the arches and their piers a length of $12 \times 7 = 84$ feet, in which case the inside length of the retort-house should be not less than 98 feet. Mr. Clegg allows 14 feet in front of each line of benches, making the whole inside width of the retort-house $14 \times 2 + 16 = 44$ feet, where a width of 16 feet is occupied by the retorts; and this is probably not too much to allow for free passage and for the operations attendant on the retorts and furnaces, such as stirring, raking out, firing, &c. The height from the firing floor

to the wall plate is usually about 14 feet, making the whole height of the retort-house from the ground line to the wall plate about 22½ feet.

The hydraulic main is usually supported by cast-iron pillars, and the roof of the retort-house is generally of wrought iron covered with slate. The coal-stores extend along each side of the retort-house; they may be abont 10 feet wide and 16 feet high from the ground line. Mr. Clegg gives for the thickness of the walls in retort-houses built by him 18 inches from the ground line to the firing floor, and 14 inches from the firing floor to the top: he states, however, that where funds are available, he would prefer increasing each of these dimensions by half a brick, at all events to the height of the coal-store, which reaches to within 6 feet of the wall plate or top of the walls of the retort-house.. There is nothing peculiar in the walls of the retort-house more than in other buildings of the same height; of course, precautions should be taken to secure a good foundation, to extend the base by footings, and, where necessary, to use piling or concrete, according to the nature of the foundation. On these points no general directions can be given, as the treatment must vary with the special circumstances of the case: the general rules, however, applicable to ordinary foundations will also apply here. The foundations of the piers, from which spring the arches under the firing floor and support the piers for the arches of the ovens above, of course require great care and attention, because any settlement after the fixing of the retorts would be very injurious. The piers must be founded on concrete where required, and it is advisable in all cases to connect them by inverted arches of 9-inch brick-work, so as to bond and tie the whole of the piers together into one broad base. Where the foundation is treacherous, the usual expedients for effecting security must be resorted to.

In arranging the number of retorts to be put up, an allowance of 1 in 4 or at least 1 in 5 should be made for retorts out of order or undergoing repair. Thus if 100 retorts are re-

quired by calculation to carbonize the coal in any given works, the establishment should contain not less than 120 to 125, in order to allow for defective retorts, &c.

The price of erecting retort-houses will of course vary with the price of labour and building materials in the district. Brick-work will vary in different parts of England from £9 to £15 per rod, and therefore it would be useless to give the prices of any particular district as a general standard for estimating.

Mr. Clegg gives an example of a retort-house 120 feet long and 48 feet wide, height from ground line to firing floor 8 feet 5½ inches, and from firing floor to wall plate 22 feet 5½ inches, thickness to firing floor 18 inches, and from firing floor to top of walls 14 inches. The quantity of brick-work in such a retort-house, including the arches and piers of the coke-stores and the whole central portion up to the level of the firing floor, would be about 1000 cubic yards, which at 25*s.* would amount to £1250.

Mr. Clegg gives the cost of this brick-work, including the cast-iron girders and York landings for the firing floor, at	£1975
He also estimates the roof at	320
Brick-work for ovens, including the setting of 150 retorts, but excluding the price of retorts, and excluding hydraulic main, stand-pipes, &c. . . .	600
Chimney, 120 feet high	180
	£3075

This retort-house contained 30 benches or 150 retorts, and was capable of producing 300,000 cubic feet of gas in 24 hours.

He also gives another example of a house not so expensively finished, being without a coke-cellar, and involving the necessity of wheeling out the coke in barrows into the open air. This house contained 8 ovens or 40 retorts, of which it was estimated that 30 would be in working order and would be capable of producing 78,000 cube feet of gas in 24 hours, so that

the works were ample for the supply of a town requiring 70,000 cubic feet of gas in the winter season.

The cost of brick-work for this house, including the roof, the chimney 70 feet high, and the setting of the retorts, was £710.

The next example given by Mr. Clegg is a retort-house containing 11 benches with 5 retorts in each, and a coke-shed built on one side of the retort-house on lower ground, so that the ground line on one side was also the floor for firing the retorts, and the falling nature of the ground gave facilities for the passage of the coke into the shed, into which it slid down an inclined plane from the front of the retorts.

This building, which was 70 feet in length, cost, exclusive of foundations, but including a chimney 90 feet high	£1200
A wrought-iron roof, slated	190
Ventilator of wood, slated	43
	£1433

	£.	s.	d.
Eleven benches of retorts, set complete . . .	220	0	0
Cost of retorts	268	2	6

The retorts were medium sized D's, each capable of carbonizing 6 cwt. of coal in twenty-four hours; so that 45 working retorts would carbonize in twenty-four hours $13\frac{1}{2}$ tons of coal, and produce from 108,000 to 120,000 cubic feet of gas.

Mr. Clegg's next example is on a much larger scale, namely, a retort-house 200 feet long and 54 feet wide, with coke-vaults on the ground floor. His estimate for this building is as follows:

Brick-work in outside walls, iron girders, flagged firing floor, and centre portion for supporting retort benches	£3950
Wrought-iron roof, slated	700
Chimney, 120 feet high	180
	£4830

M. D'Hurcourt, the author of a French work on gas-lighting, recommends a hexagon as the best form of retort-house. He proposes three entrances,—namely, one in the middle of each alternate side. In this arrangement only two-thirds of the retorts can be placed back to back, the remaining third of the whole number abutting against the brick-work of the main shaft or chimney, which is in the centre of the building. The hydraulic main is placed outside the building along each side of the hexagon, and advantage is taken of the waste heat from the retorts, all concentrated in the centre of the building, to heat one or more steam boilers, which supply a small engine that works the exhausters, the stirrers of the purifiers, pumps water into the gas-holder tanks, &c. The system of hexagonal retort-houses is not recommended with outside hydraulic mains where more than two retorts are set to an oven, on account of the complication occasioned by the numerous pipes. This kind of retort-house has never been employed for any but small works containing from 30 to 45 retorts; and, in fact, they require to be further tried before any opinion can be expressed either for or against them.

The retort-house recently erected at Kensall Green for the Western Gas Company, from the designs of Mr. G. H. Palmer, is peculiar in its arrangements. The building is a dodecagon or figure of twelve sides on the plan. The benches of retorts are ranged along the sides of the building, and are fired from the inside. According to this arrangement, the retorts are not set back to back, but in a single row. Each stack of retorts contains thirteen benches or arches, with five retorts in each. The retorts are chiefly of the York D-shape, 7 feet 6 inches long, 21 inches wide, and 12 deep; and the upper retort in some of the benches is 32 inches wide. At these works, Ramsay's Newcastle cannel is used exclusively, and as this coal does not swell in the retorts so much as the caking coal, it admits of larger charges being used; so that a bench of these retorts is capable of carbonizing nearly three

tons of coal in twenty-four hours. At the present time (mid-winter, 1853), about 152 retorts are used. Each stack of retort benches has its own hydraulic main, a reversed D, 16 inches × 14 inches. A receiving pipe 18 inches diameter passes entirely round the retort-house, and receives the gas from the separate hydraulic mains which are connected with it, and so arranged that the gas from either stack of retorts may be shut off by a slide-valve.

The chimneys of retort-houses, being usually from 70 to 100 feet in height, of course require considerable care in their foundations. Concrete or piling will frequently be required in bad ground, and all the usual precautions will be necessary to insure stability. Mr. Clegg states the price of building plain shafts in London at about 25*s.* for every foot in height above the ground line. The foundation must be separately estimated, taking excavation at about 1*s.* per yard, concrete 6*s.*, York landings 1*s.* 6*d.* per square foot, brick-work 18*s.* per cubic yard; filling in, pounding, and levelling earth 3*d.* per cube yard. These prices are lower than those given by Mr. Clegg, but they are such as a respectable builder would readily execute the work for at the present time.

The chimneys for gas-works in this country vary from 6 to 16 square feet in area, according to the number of furnaces and the extent of the works.

Mr. Barlow's estimate for a very large gas establishment, producing an annual quantity of 368 million cubic feet, and a maximum quantity of 1,800,000 cubic feet in a day, is that a retort-house or houses should be erected capable of containing 800 retorts. He estimates that each of these would be worn out after producing 700,000 cubic feet of gas, so that 526 new retorts would be required annually. He assumes that each ton of coal will produce 9200 cubic feet of gas, so that the greatest quantity of coal to be carbonized in one day in the depth of winter will be 195 tons 13 cwts. This at 5 cwt. to each retort will require 783 retorts, and at 6 cwt.

will require 652 retorts,—in the one case allowing 17 retorts, or 2 per cent. of the whole number to be ineffective, and in the latter case allowing 148, or 18 per cent. to be out of repair, or otherwise ineffective. Probably the latter supposition is the one which Mr. Barlow contemplates, as he takes his iron retorts at 16 cwt. each, which will admit of D retorts capable of carbonizing at least 6 cwt. in 24 hours, that is, capable of being worked with charges of $1\frac{1}{2}$ cwt. every six hours.

Mr. Barlow gives the size of a retort-house capable of containing 800 retorts at 640 feet in length by 52 feet in breadth and 24 feet high.

He estimates the building, including an iron roof covered with slates, at	£16,640
Coal-sheds, to contain 10,000 tons of coal . . .	9,000
Chimney, 120 feet high, with flues lined with fire-brick	450
800 retorts, namely 400 clay and 400 iron, set complete, with hydraulic main, mouth-pieces, ascension-pipes, dip and bridge pipes, complete, at £17. 15s. each .	14,200
	£40,290

The following is Mr. Croll's estimate for a retort-house capable of containing 504 retorts, including the chimney, the purifying house, coal-stores, and a boundary wall to surround the works.

	£.	s.	d.
436 rods 33 feet standard brick-work, at £11 per rod .	4797	10	0
792½ yards of concrete, at 6s.	237	14	0
Roofing, as per tender	6615	0	0
Iron floor for purifying house, 26 tons, at £10 per ton .	260	0	0
12 tons of beams to support flooring, at £10	120	0	0
504 retorts, as per former estimate, less £899. 13s. 4d. for brick-work and concrete included in the above . . .	6576	9	0
	£18,606	13	0

CHAPTER XIII.

ON THE PURIFICATION OF GAS.

We have traced the production of gas from the retorts into the hydraulic main, where it has been shown that the gas is retained by a beautiful contrivance, which, while freely admitting the gas to enter it from the retorts, opposes a seal hermetically closed against the escape of any of the gas through the empty pipes, and so back into the retorts. The gas thus collected in the hydraulic main is capable of being burnt, and was originally used in this state without purification for the purposes of lighting. By degrees, however, it was discovered that the numerous impurities with which the gas in the hydraulic main was charged rendered it unfit for burning in private houses, and one contrivance after another was adopted in order to separate these impurities, which are more particularly described in the chapter on the chemistry of gas-lighting. The process of purification is partly mechanical and partly chemical; that is to say, the tar and ammoniacal liquor are separated by a mechanical process of cooling and condensing the gas as it passes from the hydraulic main, by which process the vapours of tar and ammonia contained in the gas are condensed and allowed to pass off into separate vessels placed to receive them. The breeze condenser, or scrubber, in which ammonia is further separated by passing the gas through strata of coke dust or breeze, is a further mode of mechanical separation which is adopted in some cases. The remaining parts of the process of purification are purely chemical: they consist of passing the gas through sheets of water in certain cases, and, in purifying by Mr. Croll's patent method, of passing the gas through diluted sulphuric acid, or through a weak solution of chloride of manganese. In both

these processes the separation of ammonia is effected. The other part of the chemical purification is by means of wet lime, by slacked lime in the state of hydrate, or by means of certain other metallic oxides for the purpose of absorbing the sulphuretted hydrogen and the carbonic acid—the remaining impurities with which the gas is saturated. After the separation of these last impurities, the gas is sufficiently pure for the ordinary purposes of lighting, and it accordingly passes off to the gas-holders to be stored for use.

OF THE WASHER AND CONDENSER FOR SEPARATING THE TAR AND AMMONIACAL LIQUOR.

The importance of having an apparatus to perform this part of the process effectively is very great, because much depends upon it in future operations. If the gas reaches the lime purifiers still charged with vapours of tar, the lime is prevented from acting properly, and a much greater quantity is required to absorb the carbonic acid and sulphuretted hydrogen: besides this, the pipes and valves become choked up with tar, which also produces most unpleasant effects when the gas is burning, and is equally injurious to the stop-cocks and other parts of the fittings. Too much attention therefore cannot be paid to this part of the process, which is only effectually performed when the gas is thoroughly cooled by the time it reaches the lime purifiers.

In some country works the gas is passed through a vessel of water between the hydraulic main and the condenser. In this case it is evident that products of the same kind are deposited as in the hydraulic main, and the process is, in fact, a continuation of that to which the gas is subjected on issuing from the dip-pipes and reaching the upper part of the main. This preliminary process of washing assists the cooling, and at first separates the tar and the ammoniacal liquor very well, but in a short time the water in the wash-vessel becomes so mixed with tar, and so much resembles the fluid contained in the

hydraulic main, that it ceases to have much effect in purifying the gas; for this reason, and because it much increases the pressure in the hydraulic main, this preliminary washing cannot be recommended. It is also thought by many careful observers, that too much washing has the effect of diminishing the illuminating power of the gas by removing some of its valuable constituents.

ON THE WASH-VESSEL.

Figs. 46 to 48, drawn on a scale of 1 inch = 3 feet, show the details of a washer as used in some works between the hydraulic main and the condenser, usually where dry lime is adopted for purification. Fig. 46 is a plan looking down

Fig. 46.

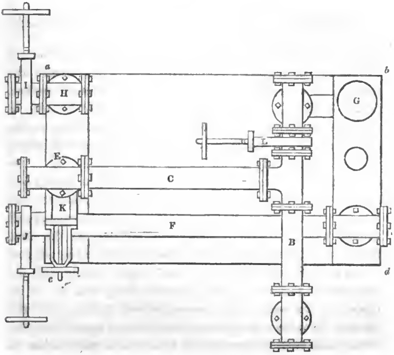
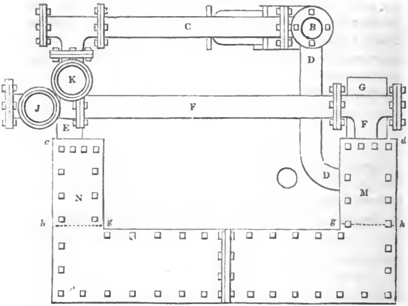
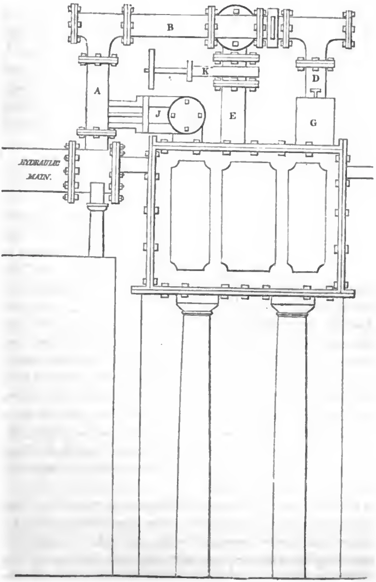


Fig. 47.



upon the washer; fig. 47 is a side elevation, and fig. 48 a front elevation. In fig. 46 *a b c d* is the iron vessel termed the washer; it is made of boiler-plates securely riveted together. In fig. 48 is seen the front elevation of this vessel, which in the engravings is about 5 feet wide and 4 feet deep at the ends, while in the middle the depth does not exceed 18 inches, as more particularly shown by the outline in fig. 47. The lower part of the vessel is filled with water to the level *g h* in fig. 47. The pipes communicating with the condenser and those by which the gas passes off from the wash-vessel are all marked with corresponding letters of reference in the three figures, and by the aid of these I shall now trace the progress of the gas. Passing from the hydraulic main (see fig. 48), the gas ascends the pipe A, and proceeds along pipe B. If intended to be passed into the right-hand extremity of the washer, the valve L is kept open, and the gas passes down the pipe D, and enters the space M. Out of this space it has no

Fig. 48.



means of escape, except by displacing the water and passing up at the other extremity of the vessel into the space N.

Arrived here, it passes up the pipe E, and finally goes off through F. If it be intended to pass the gas through the wash-vessel in a contrary direction, the valve L is closed, and the gas then goes from pipe B into C, and descends through the pipe E into N, the left-hand extremity of the washer: it then passes through the water as before, escapes into M, and goes off through pipe F as in the other case. The valves J K L, the use of which will be readily understood from an inspection of the engravings, are marked with corresponding letters of reference in each of the three figures.

THE CONDENSER.

I proceed now to describe the forms of condensers commonly in use: these are of two kinds, horizontal and vertical. The horizontal condenser is a rectangular box or chest formed of cast-iron plates, put together with flanges forming air-tight joints, and provided inside with a series of iron trays, containing each about 2 inches in depth of water, and so arranged that the gas entering at the bottom of the chest passes in succession over the surface of water in each tray, and traversing the whole length of the trough 10 or 12 times, passes off at the upper side. The condensed matters separated from the gas during this proccss are left in the water of the trays, and flow over to the bottom, from which they pass off by a pipe furnished with a stop-cock to the tank for holding the tar and ammonia, which will be afterwards described. This condenser, which is the invention of Mr. Malam, is frequently found in country gas-works.

Another form of condenser, perhaps more extensively used than the preceding, consists of a series of upright pipes 6 or 8 inches in diameter, connected with each other at top and bottom by semicircular pipes, and admitting the gas to flow freely through them. This range of vertical pipes is frequently made in large works from 20 to 30 feet in height. When made 20 feet high, every 20,000 feet of gas to be passed through in

twenty-four hours will require one pipe, and when 30 feet high, every 30,000 will require a pipe. This form of vertical condenser is sometimes used without any application of cold water to increase the cooling effect. In fact, the cooling of the gas is produced by simple radiation of heat into the atmosphere. When the upright condenser was first introduced by Mr. Perks in 1817, the pipes were not nearly so high as afterwards, namely, not more than 8 or 9 feet. They also stood in a cistern of water which entirely surrounded the pipes, in order to produce the condensation as quickly as possible. Instead of having bends at the bottom, each pipe terminated in a cell or partition half filled with water, into which the condensed products were received, and from which they were conveyed away to the tar-tank. Some difference of opinion exists as to the relative merits of horizontal and vertical condensers. It seems to be generally admitted, however, that gas moving in cylinders is not so perfectly cooled as when divided into thin strata and passing constantly over cold surfaces. In the first condenser which has been described, the trays filled with water are only about 6 inches apart, so that the gas is divided into a thin stratum, and is always in contact with water on one side and iron on the other. In passing through iron cylinders or pipes, however, the central part of the gas is not so perfectly cooled, so that there would seem to be some advantage in favour of the horizontal condenser, while, on the other hand, the upright pipes are more simple and require less attention. Horizontal condensers are also frequently composed of pipes laid horizontally, usually immersed in water.

Figs. 49 and 50 show a longitudinal section and cross section of a vertical air-condenser, with the pipes dipping into an iron trough filled with water up to the line *a a*. The longitudinal section shows that the trough is divided transversely into spaces, each of these containing two pipes which communicate freely with each other, the gas passing from one to the other over the surface of the water, and being prevented by the water from passing in any other direction. The cross

Fig. 49.

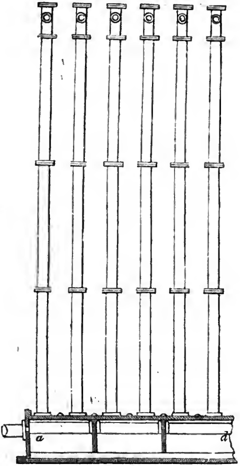
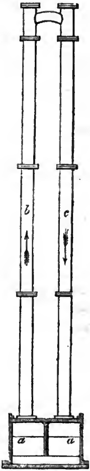


Fig. 50.



section shows that the trough is divided longitudinally into two partitions, each of which receives one row of the pipes. In fig. 50, the gas entering into the partition below the pipe *b* passes up that pipe and down pipe *c* into the next partition; then it ascends up the other pipe contained in the same partition with *c*, and so on through the whole condenser.

The condenser used at the Imperial Gas-Works in London consists of ten upright circular pipes 3 feet 6 inches in diame-

ter, standing in a shallow vessel containing water, and connected by rectangular chambers at top. The gas passes into the condenser immediately from the hydraulic main. Each pipe has an interior cylinder which admits of the free passage of air in the centre of the pipe. The gas occupies the annular space between the inner and the outer cylinder, and passes freely from one pipe to the other over the surface of the water at the bottom, and through the connecting chamber at top. This form of condenser, with some slight modification, is also adopted at the Western Gas Company's Works.

It appears from the researches of Peclet and other French writers on Physics that a very much greater extent of cooling surface is required when radiation takes place in air than where the radiation takes place in water, as when the condensing pipes are placed in that medium.

It appears, where the gas has an excess of temperature of 10 degrees over the atmosphere that a unit of surface which would radiate 8 parts of heat in the open air would radiate in water 10 degrees colder than the gas no less than 88 parts of heat; and the following Table expresses the proportionate radiation in the two cases for an excess of temperature up to 50°.

Excess of temperature in the gas.	Quantity of heat lost by a square unit of the exterior surface of pipe.	
	When radiating in open air.	When plunged into water.
For an excess of 10°	8	88
„ „ 20	18	266
„ „ 30	29	5353
„ „ 40	40	8944
„ „ 50	53	13437

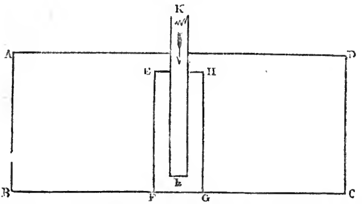
In examining this Table we find a great difference in the quantity of heat absorbed by water, especially as the excess of temperature rises, and hence it follows that if the system of condensation by simple radiation into the air be adopted, the extent of surface exposed to radiation must be much greater than when water is used, a consequence of which is an increased pressure in the hydraulic main and in the retorts, an effect which is always to be avoided if possible. It is true that in the method of cooling by means of condensing pipes immersed in water, the temperature of the latter rapidly rises, so that by degrees the advantage of this mode of cooling is lost. In order to meet this difficulty, the apparatus should be so arranged that the water may be changed as it becomes warm, and its place supplied by water at a lower temperature. Notwithstanding this arrangement, the temperature of the water will generally be more elevated than that of the atmosphere. An inspection of the Table, however, will still show the great superiority of water as a cooling medium, since water only 10 degrees lower in temperature than the gas will absorb 88 parts of heat, while air at 50 degrees lower temperature will only absorb 53 parts.

ON THE VESSELS FOR RECEIVING THE TAR AND AMMONIACAL LIQUOR PRODUCED BY CONDENSATION.

Where the ends of the condensing pipes terminate in cells partly filled with water, or where the horizontal condenser is used with trays filled with water for the gas to flow over, the products of distillation will fall to the bottom of the vessel and float on the surface of the water. From this they may be drawn off by a siphon which communicates with a tank placed below to receive them. The tank may be made of cast-iron plates, or of boiler plates riveted together, to form either a square or rectangular vessel. These tanks are also frequently built of brick or stone properly set in cement so as to be air-tight, and roofed over so as to prevent evaporation. What-

ever kind of condenser be adopted, it is necessary to make provision to hinder the escape of gas through the same pipe which carries the tar and ammoniacal liquor into the tar-tank. The mode of effecting this is shown in fig. 51,

Fig. 51.



where A B C D represents the tank, and K L the pipe open at the lower end, through which the products of condensation enter: E F G H is a cylinder of larger diameter than K L, open at the top and resting at the bottom on the base of the tank, and filled with water nearly to the top. It is evident that the tar and ammoniacal liquor discharged at L will ascend through the water and flow over into the tank at the top, E H, of the cylinder, while the pipe dipping into the water about 2 feet 6 inches forms an effectual seal against the admission of any gas.

Where an upright condenser is used, consisting of iron pipes connected at the bottom by circular pipes, a modification of the last-described method is used as follows: A cylinder, represented by E F G H, is placed under each of the circular bends, with a pipe, K L, leading into it. Immediately above the level of the water in E H, branches off a pipe secured to the cylinder by a flange and leading into the tar-tank, which runs the whole length of the range of condensing pipes. The pro-

ducts of condensation flow off through this pipe into the tar-tank instead of falling at once into the tank as they do when the cylinder is fixed in the tank, as in the first example. Sometimes the products are received into separate vessels, that from the last siphon being the most valuable.

In small gas-works, where not more than 10,000 cubic feet of gas are made in twenty-four hours, a very simple kind of condenser may be made of wrought iron by providing a sort of chest or box of boiler-plate iron, 4 feet long, 2 feet wide, and 1 foot deep. In the top of the box, four holes are to be cut to receive either square or rectangular pipes, with an area of about 50 square inches. The pipes may be made of plate iron like the box, and near the top and bottom should be connected with short cross pipes to admit the passage of the gas from one pipe to the others. The pipes may be 5 feet long, and should be inserted about 9 inches in the water with which the box is to be filled. The gas is admitted at the top of the first pipe and passes off at the top of the last pipe. The chest to receive the products of condensation to be connected with a tar-tank in the usual way. In estimating the size of the tar-tank, it is usual to calculate that each ton of coal produces from 100 to 140 ℔s. of tar, and from 10 to 13 imperial gallons of ammoniacal liquor, and it is proper to have the tank large enough to hold about six weeks' production of tar and ammoniacal liquor. According to this calculation, a capacity of about 100 cubic feet will be required for each ton of coal carbonized in twenty-four hours.

Mr. Peckston gives the capacity of a tar-tank at 540 cubic feet for a small gas-work where twenty small D retorts are used in the winter months, the amount of coal carbonized at midwinter being about 5 tons; and this size of tank agrees very nearly with that which would be determined by allowing 100 cubic feet for each ton of coals.

Where the system of cooling by radiation in air is adopted, it is very advisable in dry and warm weather to assist the cooling by allowing small streams of water to trickle down

on the outside of the condensing pipes: this is effected by having a cistern of water fixed over the pipes. The cooling effect of this water evaporating on the outside of the pipes is greater than if the latter were placed in water, owing to the great quantity of caloric which passes from a sensible to a latent state during the formation of vapour. The more rapidly the vapour is formed the greater will be the cooling effect, from which it follows that the effect will be greatest when the sun shines most powerfully, and that the condenser should always be exposed as much as possible to the direct rays of the sun.

The mode of inserting the pipe conveying the tar and ammoniacal liquor from the condenser into the tar-tank, so as to seal up the pipe and prevent the escape of gas, has been already described. A similar connection must also be made between the hydraulic main and the tar-tank, into which a pipe having a slight inclination conveys the surplus tar and ammoniacal liquor left by the gas in passing through the hydraulic main. It has been already explained that the hydraulic main is first filled about half full with water, but this is soon displaced by the products from the gas, and in time consists almost entirely of tar. In the tank both the tar and ammoniacal liquor are contained; they are not mixed together, however, because the ammoniacal liquor being of less specific gravity than the tar floats on the top. The heaviest and most valuable tar is always underneath.

When either of the liquids contained in the tar-tank is required, it is pumped out by means of a pump with a moveable suction-hose, which can be adjusted so as to have its orifice either in the ammoniacal liquor or in the lighter or heavy portion of the tar, by which contrivance either description of liquid can be pumped out as required.

At some gas-works, both the tar and the ammoniacal liquor are sold, the usual price for tar being about 1*d.* per gallon, and for ammoniacal liquor one farthing per gallon.

Estimates and Specifications for Condensers.

The evidence taken in 1849 and 1850 before the Parliamentary Committees which sat on the Great Central Gas Consumers' Bill, affords some valuable information on the subject of prices and the general construction of large works. In 1849, the project brought forward by Mr. Croll, the Engineer of the Company, contemplated an annual production of 368,000,000 cubic feet of gas, and the estimate for condensers in a gaswork of this magnitude was £1237, exclusive of a concrete foundation, which would cost £5 or £6 more.

Mr. Barlow, in his Report to the Directors of the City of London Gas Company, made no objection to this amount, and adopted it in his own estimate. This estimate is equal to ·807*d.* per 1000 feet of gas per annum, or £1·23 per 1000 feet of average daily production. Mr. Croll proposed to use for this condenser 128 pipes, each 9 feet in length and 18 inches diameter, to have a box at top and bottom of condenser divided into partitions, so that the gas should pass alternately up one pipe and down another. The entire length of pipe for condensing which Mr. Croll calculates on, would be $128 \times 9 = 1152$ running feet. This gives rather more than 1 foot for every 1000 feet of gas made in 24 hours; the length required according to this calculation being 1008 feet. The following is a summary of Mr. Croll's estimate for this condenser:

	£.	s.	d.
130 tons 13 cwt. 1 qr. 5 lbs. of cast iron, at £9. per ton .	1175	19	7
3692 lbs. of wrought iron in bolts, &c., at 4*d*. . . .	61	10	8
	£1237	10	3

In the following year, 1850, the first Bill having been thrown out in the Committee of the House of Commons, the promoters brought forward a revised estimate for the construction of works capable of producing 320 million feet of gas annually. They had in the mean time entered into contracts with Messrs. Rigby, the extensive builders, and the specifications on which Messrs. Rigby's contracts were founded were

produced in evidence. I make no apology for quoting this Specification at length, as it serves as an excellent model for works of magnitude.

VERTICAL CONDENSER.

Condensers.—To be two in number, constructed each of a bottom box 38 feet 2 inches long by 4 feet wide and 2 feet deep, inside measurement, with sixteen double rows of upright pipes in two 9-feet lengths, each 18 inches in diameter; the whole connected at top to a box the same length and width as the bottom box, but only 1 foot 6 inches high, having an ornamental front and ends, as shown in the drawings.

The bottom and top boxes to be partitioned off, so that the gas may circulate through the pipes in rotation.

The bottom box to be in eight lengths, and constructed as follows:

The bottom plates to be 4 feet 9 inches square, with a flange on two opposite ends $2\frac{3}{4}$ inches clear of the plate, with stiffening brackets, and bolt-holes 6 inches apart; the plate to be $\frac{5}{8}$ths of an inch thick.

The side plates to be 4 feet 9 inches by 2 feet, with a $2\frac{3}{4}$-inch flange clear of the plate all round on the outside, and brackets with bolt-holes 6 inches apart, centre to centre; a bead to be cast on the outer surface. A flange $2\frac{1}{2}$ inches broad to be cast up the inside of this plate for the purpose of bolting partitions to.

The top plates to be 4 feet 9 inches square, with a flange on the outside on two opposite ends, $2\frac{3}{4}$ inches clear of the plate, with brackets and bolt-holes 6 inches apart, centre to centre; four sockets, 5 inches deep each, to receive an 18-inch pipe, to be cast upon its upper surface, leaving an equal margin all round the plate, their distance from centre to centre being 2 feet 5 inches; six fillets to be cast up each of these sockets.

Division plates, in the under box to be fifteen in number, eight of them 4 feet 2 inches long, bolted to the flanges, which are cast on the inside of the side plates; the remaining seven

to be 4 feet 9 inches; the depth of these plates to be 2 feet in the centre and 1 foot 6 inches at each end, with a flange along the top 1½ inch broad, without any bolt-holes.

The end plates to be quite plain, extending to the outer edge of the flanges of the top, bottom, and side plates, with bolt-holes to fit those in the box, having two cleaning holes, fitted lids, and bolts.

Upright pipes.—The first length that fits into the top plates of the bottom box to be spigot and socket pipes; the next length, and which connects to the top box, to be spigot and flange pipes; the whole to be 18 inches in diameter, cast upon end, and as thin as is consistent with proper security.

Top box to be 37 feet 6 inches long, 4 feet 1 inch wide, inside the projections, and 1 foot 4 inches high inside the top cover, which will be fixed 2 inches from the top of the side plates. The box to be partitioned off by a longitudinal partition running the entire length of the box, and fifteen cross partitions bolted to it and to the side plates; these partitions to be ½ inch thick, all bolted together by ½-inch bolts 6 inches asunder, centre to centre, through flanges 2 inches clear of the plate, jointed with iron cement; the partitions to be 1 foot 4 inches deep. The plates which form the box to be in eight lengths, each 4 feet 9 inches long.

The bottom plate to be 4 feet 9 inches long by 4 feet 6 inches wide, with flanges on two ends, standing 2½ inches clear of the plate looking down; this plate to be ⅝ths thick, with four holes cast in it 2 feet 5 inches apart, centre to centre, it being understood that these holes shall fit the upright pipes, which are to be bolted to this plate by six ¾-inch bolts each.

The front side plate to project, as shown on the plan, with side flanges 2½ inches clear of the plate looking to the inside, and a flange 2½ inches broad running horizontally at a level of 2 inches from the top on the inside; the flange at bottom, by which it will be bolted to the bottom plate, to stand on the outside 2½ inches clear of the plate; the bolt-holes in the whole of these flanges to be 6 inches asunder, centre to centre.

The back plate to be of the same length and height as the front plate, with all its flanges arranged in the same manner and of the same dimensions, having an additional flange cast up its centre 2 inches clear of the plate, for the purpose of bolting the short partitions to.

The end plates to project similar to the front plates, having the projection returned on the corner, thereby forming the extreme ends of both front and back plates, and bolted to the side and bottom plates by inside flanges in the same manner as the side plates are; a horizontal flange to run along the inside of each end plate, to bolt the ends of the top plate to, at the same level as the horizontal flange upon the inside of the side plates.

The top plate to be in lengths corresponding with the bottom plate, and 4 feet 6 inches wide, $\frac{1}{2}$ inch thick, and bolted to the horizontal flange cast on the inside of the side plate, having four 12-inch holes cast in it 2 feet 5 inches, centre to centre, and lids to suit. This plate to have two flanges looking up, $2\frac{1}{2}$ inches broad, one on each end, with bolt-holes 6 inches apart, centre to centre.

Conclusion.—The whole of the above work to be of the best cast and wrought iron; the castings to be perfectly sound, smooth, and geometrically true; the flanges in the bottom box to be made fast by $\frac{3}{4}$-inch bolts and nuts; those in the upright pipes to be $\frac{7}{8}$-inch bolts, and those in the bottom of the top box $\frac{5}{8}$-inch bolts; the remainder of the top box to be fastened by $\frac{1}{2}$-inch bolts; the whole of the joints to be made of clean iron cement firmly caulked in, and made perfectly gas-tight, and to the satisfaction of the Company's Engineer.

HORIZONTAL CONDENSER.

This condenser to be constructed as follows: Thirty-two lengths of 18-inch pipe, each 9 feet long, cast as thin as they can be with proper security; six of the above to be flange and socket pipes, and six of them to be flange and spigot pipes,

the remaining twenty to be common spigot and socket pipes; five semi-flange bends to connect the ends of the pipes, with a flange cleaning-branch cast on, which will be bolted to the ends of the water-tank in which the pipes will be placed; this branch to be of the same diameter as the pipes.

Two flange bends, forming the inlet and outlet, of the same diameter as the other pipes, to be connected to the bottom of the water-tank, their flanges at such a height as will allow the under side of the pipe to be 3 inches from the bottom of the tank. The whole of the flange-joints to be made with mill-board and red-lead well screwed up, each with six $\frac{3}{4}$-inch bolts; the socket-joints to be run with lead in the ordinary manner.

The above pipes will rest in a tank 61 feet long $\times$ 16 feet wide $\times$ 3 feet 6 inches deep, made of cast-iron plates, with a cast-iron beam 17 feet long, 9 inches deep in the middle, and 6 inches deep at each end, to be in section thus ⌶, one below every joining in the plates, or eleven beams in all; the ends of the tank to rest on the walls of the house.

The bottom plates to be $\frac{5}{8}$ths, and those on the sides to be $\frac{1}{2}$ an inch in thickness, all firmly bolted together by $\frac{5}{8}$ bolts not more than 6 inches apart, centre to centre; the flanges to be $2\frac{1}{2}$ inches broad, clear of the plates, with proper strengthening fillets, one between every two holes; the joints to be made of good iron cement firmly caulked in.

On one end of the tanks the end plates will each have an 18-inch hole cast in them, and lid to suit, fastened on by mill-board joints with six $\frac{3}{4}$-inch bolts.

The holes in two of these plates will be at the same level, that level being so that the pipes which join on will have 1 inch of rise from their other end, which is fastened to the bottom of the tank; the hole in the remaining plate will be in the centre of its length and 3 inches higher than the hole on each side of it.

On the other end of the tank there will be two holes, fitted in every respect as the ones just described, both at the same

level, that level being $1\frac{1}{2}$ inch below the highest hole in the opposite end; the arrangement being that the whole of the pipes shall have a fall one-half to the inlet, the other to the outlet.

Twenty-six stays of $\frac{3}{4}$ round rod to be bolted 1 foot from the top of the sides stretching across the tank, one to every joining in the plates.

The whole to be gas and water tight, receiving two coats of red-lead oil-paint.

HORIZONTAL CONDENSER.

	tons.	cwt.	qrs.	lbs.
Cast Iron.				
Tank	18	16	0	12
Pipes	16	8	2	20
Supporting beams	4	8	3	26
	39	13	3	2
Wrought Iron.				
Bolts and stays	0	18	3	24

TWO VERTICAL CONDENSERS.

	tons.	cwt.	qrs.	lbs.
Cast Iron.				
Bottom box	9	11	2	14
Pipes	34	0	0	0
Top box	6	13	1	10
	50	4	3	24
Wrought Iron.				
Bolts	0	11	3	11

It will be seen from the preceding Specification that there were to be two vertical condensers, each with thirty-two lengths of 9-feet pipe, 18 inches diameter, and one horizontal condenser, with thirty-two lengths of similar pipe, or in all, ninety-six lengths, or 864 lineal feet of pipe for a daily average production of 876,000 cube feet of gas, being somewhat less than 1 foot of pipe per thousand feet of gas. According to Messrs. Rigby's schedule of prices, the following would be the cost of the three condensers:

	£.	s.	d.
Cast iron, 89 tons 18 cwt. 2 qrs. 26 lbs., at £9. per ton .	809	8	7
Wrought iron, in bolts and stays, 1 ton 10 cwt. 3 qrs. 7 lbs., at 4*d*. per lb.	57	10	4
	£866	18	11

Or at the rate of 19*s*. 9*d*. per thousand feet of average daily *production*.

THE EXHAUSTER.

This is an apparatus which has been introduced into modern gas-works for the purpose of drawing off the gas and relieving the pressure in the retorts. The modern refinements insisted on with reference to the purity of the gas all contribute to increase this pressure, as every time the gas passes through a fluid of greater density than itself, a resistance is occasioned which adds to the pressure on the retorts, and this pressure at length becomes so great that means must be resorted to for diminishing it. In the first place, the contrivance of sealing the dip-pipes in the hydraulic main requires the gas to force its way through several inches of tar before it can escape from the retort, and this is the first resistance which it meets with. In many works where dry lime is used in the purifiers, the gas is passed through water in the wash-vessel, where the gas is again resisted, and the pressure of course increased. In the dry-lime purifiers and in the breeze condensers, or scrubber, it is not considered that any sensible resistance is opposed to the passage of the gas; but in some works, both a washer and a series of wet-lime purifiers are used, in which the pressure becomes considerable, and an exhauster is found almost indispensable. The weight of the gas-holders also adds materially to the pressure of the gas in the retorts.

About twelve years ago it was ascertained by Mr. Grafton, in the course of some experiments at Cambridge, that the carbonaceous deposit in the retorts was due almost entirely to the pressure on the gas. Previously to this discovery, it was generally considered by the most scientific authorities that the

deposit of carbon was due to high degrees of heat and too great an extent of heating surface. In addition to the injury of this deposit to the retorts themselves, causing them to burn out with great rapidity, and the expense of frequently removing the deposit, there is every reason to suspect that some of the very best constituents of the gas, namely, the volatile hydro-carburets, are decomposed and condensed in this deposit, and that the gas is thereby much impaired in quality. In addition to this the pressure causes an increase in the quantity of tar, an effect which never takes place except at the expense of the gas. Mr. Grafton conducted his experiments in such a way as to show very practically the truth of the conclusion he had arrived at. By increasing the pressure till it became equal to a column of 14 inches of water, he produced in a single week a deposit 1 inch in thickness, and at the expiration of two months it had filled up nearly one-fourth of the retort. During this experiment a deposit weighing 10 cwt. 24 lbs. was produced by the carbonization of sixty-seven tons of Wall's End coal. An experiment under entirely opposite conditions was then made, all the pressure being taken off except that arising from half an inch dip into the fluid of the hydraulic main. Under these circumstances, when the retort was again worked with the same description of coal for four months, scarcely any deposit had taken place.

The earliest form of machine used for taking off the pressure was a pump, on the principle of the Archimedean screw, which was used for pumping the gas from a higher to a lower level. The screw was so placed that the upper extremity of the axis was nearly on a level with the surface of a small reservoir of water. The screw revolves in an opposite direction to that required for pumping up or raising liquids; and at each revolution the upper mouth of the helicoidal canal takes in a certain quantity of gas, after which follows the water. The gas descends along the spiral canal of the screw in proportion to the rate of revolution in the latter, and having reached the lower end of the canal, passes off by a pipe with an excess of

pressure measured by the height of the surface of the water above the lower extremity of the screw.

Another kind of extractor, which does not require so rapid a movement as the Archimedean screw, consists of a circular drum with four divisions formed by curved plates proceeding from the centre to the circumference. The wheel revolves in a cistern filled with water to the height of three-fourths the diameter of the wheel, and each of the chambers, formed by the divisions spoken of, carries down below the surface of the water a certain portion of gas, which is delivered out of the drum into a pipe passing off at the level of the centre of the wheel. This pipe opens into a chamber containing water about an inch higher than the upper surface of the pipe, and the difference of level between the water in the cistern and in the chamber which the gas now occupies indicates the difference of pressure. If the pressure be not sufficiently reduced by passing the gas through one drum of this kind, it goes on to a second or a third, till the required diminution has been attained.

In some works the extractor is placed between the hydraulic main and the condenser, in which case the washer, if employed at all, is used after the purification by dry lime. In other works the extractor is employed after the purifiers, in which case the wash-vessel is frequently dispensed with, as the action of the extractor in passing the gas through water forms a substitute for the action of the wash-vessel.

Mr. Grafton has also used his extractors for the purpose of purification by lime instead of passing the gas through a separate vessel for this purpose. He places lime in the corners of the cistern in which the drum revolves, and relies on the revolution of the drum to keep up a sufficient agitation of the lime.

In works where the whole of the purification is effected in the dry way, and where no wash-vessel is used, an exhauster is unnecessary. The gas at the works of the Western Company has seldom a pressure in the hydraulic main exceeding 6 inches. Here the whole of the purification is effected by dry materials, and an exhauster is not used.

Probably the most improved form of exhauster is that adopted by the Chartered Company at their Westminster Station. The gas is passed through a series of air-tight chambers, usually three in number, in each of which works a circular disk, on the same principle as the disk engine. By this contrivance the gas is pumped off as it were, and the pressure can be reduced to any amount required. It is impossible in a work of this kind without the aid of plates to give anything like a description of this exhausting machinery. An engine on the same principle was shown in the Great Exhibition by Messrs. Donkin, who erected the exhausting apparatus for the Chartered Company.

I conclude the subject of pressure by observing, that it would be dangerous to remove all the pressure from the retorts, as in case of any accident atmospheric air might be introduced in such quantity as to form an explosive compound, from which very serious mischief might result.

ON THE SCRUBBER OR BREEZE CONDENSER.

This is used in some works to separate the ammonia instead of a wash-vessel, the gas passing from the radiating condenser into the scrubber or breeze condenser, then to the wet-lime purifier, and then to the gas-holder; or where dry lime is used, it is an improvement to pass it lastly through a wash-vessel between the purifier and the gas-holder. The breeze condenser consists of a series of trays or sieves composed of round iron rods or wires about $\frac{5}{16}$ths of an inch in diameter, placed all in one direction for the convenience of cleaning and raking out the contents. These sieves are placed about 6 or 8 inches apart, and the spaces between them nearly filled up with layers of coke-dust, cinders, or brick-dust, through which the gas ascends from the bottom and passes off at the top, depositing its ammonia in its progress. The contrivances for sealing the top of the scrubber by a water-joint, and also sealing the delivery-pipe so that the escape of gas is impossible, and the

parts so sealed can be easily removed, are similar to those which will be described for the lime purifiers.

ON THE PURIFICATION OF GAS FROM AMMONIA.

I have already alluded to the wash-vessel as a contrivance for separating ammonia, and to the breeze condenser which is used in some works for the same purpose. When both these modes of purification are adopted, the separation of ammonia is tolerably perfect; but of course the ammonia is entirely lost, and the separated products have no commercial value whatever. When the breeze condenser alone is used, the gas is not entirely freed from essential oils, but the whole of the olefiant gas is also retained, so that it has been contended that the presence of the olefiant gas more than counterbalances the injury done by the other slight impurities. When a wash-vessel is used either with or without the breeze condenser, the essential oil is separated together with ammonia, and if used before the lime purifiers, a portion of sulphuretted hydrogen and carbonic acid gas is also separated. It is also probable that some of the olefiant gas and other heavy carburets are at the same time absorbed by the water. As this would much impair the quality of the gas, the use of the wash-vessel is sometimes dispensed with, and the breeze condenser alone relied on for the purification from ammonia.

MR. CROLL'S PROCESS FOR SEPARATING AMMONIA BY PASSING THE GAS THROUGH SULPHURIC ACID, OR THROUGH A METALLIC SOLUTION.

This process having within the last few years been brought prominently before the notice of the public, and being now adopted on an extensive scale at the large works of the Great Central Gas Consumers' Company at Bow Common, I have thought that some account of the method pursued will be interesting.

Mr. Croll's patent is for separating ammonia between the condenser and the purifiers.

He effects this by means of chloride of manganese used in separating vessels. Ammonia diminishes the illuminating power of the gas, and also corrodes and destroys the meters and fittings. It acts more especially on brass-work, forming an ammoniurate of copper, which gives a blue tinge to water, and is always found in water-meters through which gas has passed for a considerable time. By the use of chloride of manganese, Mr. Croll also expects to separate a considerable part of the sulphuret of carbon, which will combine with the manganese, and prevent that close disagreeable effect which is frequently complained of in burning gas which has not been purified by a metallic salt.

Mr. Croll further calculates by using chloride of manganesc to save one-half or one-third of the lime otherwise required for purification, and at the same time to procure a valuable production in the shape of chloride of ammonium or sal ammoniac.

It appears that the object of separating ammonia between the condenser and the purifier can also be effected by passing the gas through vessels containing dilute sulphuric acid, which vessels may be made either of wood or iron, but must be lined with lead. This process was first proposed by M. Darcet in 1816, and is said to bc highly successful in separating sulphate of ammonia, which is an article readily disposed of. Mr. Croll's method of purification is now extensively practised at the Central Gas Consumers' Works and also by the Imperial Gas Company, who have bought a licence to use the process.

Mr. Croll states that the ammoniacal salts present in gas are the hydrosulphuret of ammonia and the cyanuret of ammonia. In the condenser a considerable quantity of the hydrosulphuret of ammonia is removed, but a large proportion of ammonia still remains, and, notwithstanding the ordinary modes of purification, passes into the mains, to the great destruction of the meter and gas fittings. The ammoniacal liquor is commonly sold to manufacturing chemists, who procure about 14 ounces of sulphate of ammonia from a

gallon of the liquor. This salt of ammonia is prepared by adding sulphuric acid in excess to the ammoniacal liquor, and purifying the crystals obtained on evaporation. Chloride of ammonium or sal ammoniac, which was formerly procured from the camels' dung of Egypt and Syria, is also now largely manufactured from ammoniacal liquor. This salt is prepared by adding hydrochloric acid in excess; the mixture is then evaporated to dryness, and the salt carefully heated, to expel or decompose the tarry matter in the liquor. It is then purified by sublimation in large iron vessels lined with clay and surmounted with domes of lead. It is singular that the method of purifying gas which has lately been patented by Mr. Croll was proposed by M. Darcet, a Frenchman, as long ago as 1816. He proposed to use a leaden vessel, containing either diluted sulphuric acid, or a solution of iron or lime in sulphuric acid. M. Darcet anticipated from this method a much better effect than from passing the gas through a simple sheet of water, besides which he attached considerable importance to the new product, sulphate of ammonia, which forms so prominent a feature in Mr. Croll's patent.

Another great advantage of the process is, that dry lime may be used for the purifiers. The objection to purification by wet lime is, that considerable pressure on the retorts is requisite to force the gas through the fluid lime. The consequence of this is that the retorts are much injured by an incrustation of carbon, and that considerable power is required for exhaustion and for agitating the liquid lime.

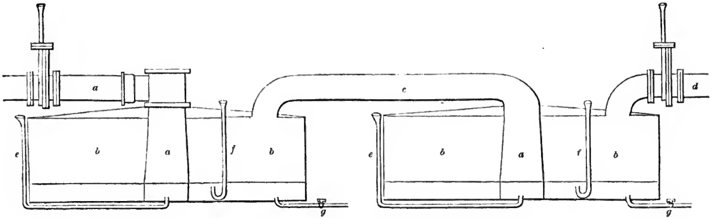
The wet lime purifies the gas from sulphuretted hydrogen and carbonic acid; it also retains some portion of the hydrosulphurets and other salts of ammonia, but allows a considerable quantity of ammonia still to pass off with the gas. Generally in the country the dry-lime purifiers are used; but these are found to be highly objectionable and offensive in towns, owing to the volatility of the hydrosulphuret of ammonia, which does not chemically combine with the lime, but is merely held in mechanical combination. Also when the dry-

lime purifier is opened and exposed to the air, a union takes place between the hydrosulphuret of lime formed in the purifier and the oxygen of the atmosphere. By this union, sulphate of lime is formed, and considerable heat is evolved, which renders the sulphuret of ammonia still more volatile and occasions a most insufferable stench, which is besides highly injurious to animal life. These inconveniences have led to the adoption of wet-lime purifiers at most of the large works, although Mr. Clegg and nearly all the authorities in gas engineering give a decided preference to the dry lime. By Mr. Croll's separate process for abstracting the ammonia between the condenser and the purifier, no objection whatever remains against the use of dry lime, and accordingly it may generally be used where this process is adopted.

Mr. Croll's method of purifying the gas from ammonia may be effected either with the chloride and sulphate of manganese, with the chloride and sulphate of zinc, or by means of diluted sulphuric acid contained in vessels lined with lead, in order to resist the action of the acid.

The vessel used is generally circular in form, about 10 feet in diameter and 3 feet deep. The bottom of this vessel is formed by a circle with wooden ribs or radiating bars 8 or 10 inches in depth: this wooden circle completely occupies the bottom, and supports a leaden plate 10 inches less in diameter than the vessel, so that a spaee of 5 inches is left all round it. Diluted sulphuric acid consisting of $2\frac{1}{2}$ ℔s. of acid (Dr. Ure says 7 ℔s.) to 100 gallons of water are then poured into the vessel up to the height of the leaden plate. The gas to be purified is brought to the vessel by a pipe which passes through the leaden plate and dips into the acid solution, the divisions by which the plate is supported completely separating and subdividing the gas so as to bring each portion of it in contact with the dilute acid. As the acid becomes neutralized in a short time, a regular supply of it is kept up by means of a small reservoir placed outside, from which the acid is allowed to drop or trickle into a funnel, and conveyed by a small tube

Fig. 52.



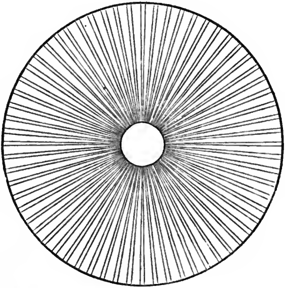
down the side of the vessel and brought in under the leaden plate, as shown in the wood-cut, fig. 52.

The vessel is furnished with another pipe for conveying away the gas to the lime purifiers, with a small tube for adding supplies of water, and with a discharging-pipe and stop-cock. The original proportion of acid is kept up as nearly as possible until the solution attains, when tried by the hydro-

meter, a specific gravity of 1170, which is nearly the point of crystallization. The supply of acid is then discontinued, the liquor retained in the vessel, and the gas again passed through until the solution becomes neutral, when it is drawn off and evaporated, and yields a pure sulphate of ammonia.

In large works it is preferable to use two vessels for separating the ammonia, in order to insure with more certainty the entire abstraction of all the ammonia, since the gas passing twice through the dilute acid will be better purified than if only treated in one vessel, where there may have been an accidental or temporary deficiency of acid. Two vessels of the size here described, namely, 10 feet diameter and 3 feet deep, will purify 500,000 feet of gas in twenty-four hours, and will require to be charged with the acid solution once in two days.

Fig. 53.



Figs. 52 and 53 show the arrangement made use of by Mr. Croll for purifying the gas. Fig. 52 is a section of the vessels,

each 10 feet diameter and 3 feet deep. *a* is the inlet-pipe, passing nearly to the bottom of the vessel; *b* is the circular purifying vessel, lined with lead, in order to withstand the action of the acid: the bottom of this vessel is composed of a series of radiating plates of wood, shown in fig. 53, standing about 8 or 10 inches above the bottom. On the top of these radiating bars of wood rests the leaden dash-plate, as already described. *c* is the pipe leading from one purifying vessel to the other, and *d* is the pipe by which the gas makes its exit; *e e* are the pipes provided with funnels, by which the sulphuric acid is added; *ff* are the pipes for the supply of water, and *g g* are the pipes by which the liquid sulphate of ammonia is drawn off.

The neutral liquor drawn off from the vessels yields on evaporation 80 ounces of sulphate of ammonia per gallon, instead of the 14 ounces per gallon yielded by the ammoniacal liquor separated in the condenser. It is anticipated that the adoption of Mr. Croll's method of separating ammonia from the gas before it reaches the lime purifiers will enable all Gas Companies to return to the use of dry-lime purifiers. When there are no longer any volatile salts of ammonia in the dry-lime purifier, the noxious effluvia so much complained of in the neighbourhood of gas-works, and so injurious to the health of the workmen, will be no longer experienced. Mr. Croll states that since the introduction of this method by several of the large London Companies, the dry-lime purifiers have again been made use of without any inconvenience or complaints whatever. The products now separated by the dry-lime purifier are all salts of lime, which are by no means volatile, and are at the same time highly valuable for agricultural purposes.

This description of the purifying process is taken from a paper by Mr. Croll, read before the Institution of Civil Engineers some years ago. At that time diluted sulphuric acid appears to have been the contemplated purifying medium. The patent, however, also included the use or substitution

of metallic solutions. In point of fact the material now used by the Imperial Gas Company is muriate of manganese, a product of no great value derived in the manufacture of chloride of lime or bleaching powder. The muriate (or, more correctly speaking, the chloride) of manganese is dissolved in water, and used in vessels similar to those just described, or it may be used in ordinary wet-lime purifiers. It requires to be renewed every two or three days, according to the quantity of gas passed through it. I am informed that Mr. Croll is also using chloride of manganese in solution at the Bow Common Works.

It is said that a great saving of expense from the use of dry lime has been effected by all those Companies who have adopted Mr. Croll's process. A great reduction has also been made in the expense of repairing meters and public street lamps. In addition to these advantages, it is said the illuminating power of the gas is increased 5 per cent., while its freedom from ammonia renders the gas perfectly fit for use even in bed-rooms and the most elegant drawing-rooms, where it was formerly objected to on account of its injurious effects on gilding and metallic surfaces.

An impression has been entertained by agriculturists that in consequence of the abstraction of ammonia before the gas enters the dry-lime purifier, the waste or spent lime will be deprived of much of its useful effect, hitherto supposed to be due to the presence of ammonia. Mr. Croll, however, contends that the refuse dry lime as at present sold by the Gas Companies consists merely of sulphate, carbonate, and cyanuret of lime, all the ammonia being lost by volatilization long before the lime can possibly be delivered from the works; hence he believes that the refuse lime will possess precisely the same valuable properties as a fertilizer, while the noxious exhalations which accompanied the escape of ammonia on the opening of the purifiers will be entirely avoided.

The saturated liquor drawn from Mr. Croll's purifying vessels after being evaporated leaves sulphate of ammonia in

great purity, the quantity of ammonia being equal to 30 parts in 100. The fertilizing power of this sulphate is very considerable, and has been attested by numerous agriculturists. It is said, when used as a top dressing on grass lands, to have added half a ton of hay per acre to the produce, and in wheat crops to have increased the weight of the wheat so much as to add considerably to its selling price. About 1 cwt. per acre is said to be a profitable dressing either for wheat or grass land. The manufacture of sulphate of ammonia at the various gas-works is likely to become of considerable importance: many tons are already produced weekly from those works where the process is introduced. When an increased production of this valuable article takes place also, the agriculturist will be further benefited by a reduction of price, as in the case of sal ammoniac and carbonate of ammonia, the price of which was formerly 3*s.* per pound, while, since the increase of gas-lighting, and the consequent production in large quantities of ammoniacal liquor, a superior quality of sal ammoniac is sold for 6*d.* a pound.

ON PURIFICATION BY MEANS OF LIME.

It is remarkable that the two principal authors on gas-lighting in this country agree in condemning the use of wet-lime purifiers for large towns, on account of the nuisance occasioned, and the difficulty of getting rid of the spent lime-water. It seems to be agreed on all sides that dry lime is preferable where it can be used, as it causes much less pressure on the retorts, and renders an engine unnecessary, except in large works where there is other employment for it. It has been found, however, owing to the causes already explained, that the dry-lime purifiers give out such offensive effluvia that most of the London Gas Companies have been obliged to abandon them and adopt wet lime. It remains to be seen whether the complete separation of ammonia effected by Mr. Croll's process before the lime purification will again lead

to the general establishment of dry-lime purifiers. Before proceeding to describe the vessels used for purification by lime, it should be explained that by dry lime is meant, not quick-lime absolutely unmixed with water, but quick-lime with just sufficient water added to slack the lime and reduce it to powder, in which condition it is chemically called hydrate of lime: in this state the hydrate is spread on the sieves of the purifier. By wet lime is understood a fluid mixture made by adding water to slacked lime in the proportion of 24 gallons of water to 1 bushel of lime, the mixture having almost the consistency of cream, and being termed by the French 'milk of lime.' It should be observed, that lime when slacked will occupy about double the bulk of the quick-lime; so that if the lime be measured before slacking, the proportion of water will be 48 gallons to every bushel of unslacked or quick-lime.

DRY-LIME PURIFIERS.

In Mr. Clegg's excellent work on gas, there is a plate explanatory of the construction of dry-lime purifiers, in which one purifier out of a set of three is shown in detail, the gas passing from one purifier to the other. The purifier consists of a square iron box 6 feet long by 5 feet wide and 3 feet deep: the inlet-pipe from the wash-vessel is 8 inches inside diameter, and enters at the bottom of the purifier; a few inches above the mouth of the inlet-pipe is fixed a plate about 2 feet square, which serves the purpose of distributing the gas and preventing any of the lime from falling into the inlet-pipe. The purifier contains three tiers of trays or sieves placed 6 or 8 inches apart, and resting on snuggs cast on the inside of the purifier: each tier contains four trays, each tray being about 2 feet 8 inches × 2 feet 4 inches, so that one purifier contains in all twelve trays or sieves, the bottom of each being composed of round rods $\frac{5}{16}$ inch diameter placed about $\frac{1}{2}$ an inch apart. The top of the purifier is an inverted box 6 feet by 5 feet, and with sides and ends 10 inches deep, fitting into a water-lute 12 inches deep, so that the gas is enclosed by a

seal of at least 10 inches in depth of water: the outlet-pipe passing out of the lid of the purifier is 8 inches inside diameter, and is made in the form of a semicircle whose inside diameter is 2 feet: the other end of the semicircle joins another pipe, which is fixed. Each end of the semicircular outlet-pipe dips into an annular space containing 10 or 12 inches in depth of water, so as to form a water-seal similar to that described for the cover of the purifier. These water-joints give the utmost facilities for removing the semicircular pipe and the cover of the purifier whenever required for the purpose of cleaning out or otherwise, without breaking any solid joint or doing injury to any part of the machine. Mr. Clegg states that two bushels of the hydrate of lime will spread over a surface of sieve equal to 25 square feet, with a depth of 2½ inches, which in practice is found about the best thickness; and that this quantity, which is equal to one bushel of quick-lime, will in some places purify 10,000 cubic feet of gas, while in other places double the quantity of lime will be required.

The purifier here described by Mr. Clegg is rectangular in form, but circular ones are equally common; they are seldom made more than 3 or 4 feet in depth, on account of the extra labour required in deep purifiers for shifting and replacing the trays.

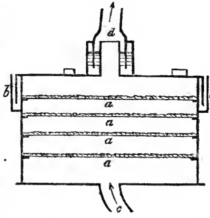
In most of the French gas-works the hydrate of lime is placed on beds of moss which are first spread on the trays, or the latter contain alternately a layer of moss and a layer of lime. The use of the moss is to subdivide the gas into the thinnest possible sheets and streams, so that every particle of it may be brought into contact with the lime.

The purifiers generally used in the French gas-works are from 3 to 4½ feet in depth, and they are generally made circular, from 4 to 8 feet in diameter, according to the size of the works; in these are placed three or four trays, which contain layers of lime and moss. When the lime is spread upon moss it is usual to employ rather less than a bushel of lime per square yard of purifier. In most of the French works the quantity

of lime used for purification is at the rate of about $2\frac{1}{2}$ bushels per ton of coals, which yield on an average less than 7000 cubic feet of gas per ton. The usual calculation with them is that a purifier with an area of one square metre or $10\frac{3}{4}$ feet is required for every 10 hectolitres (2800 lbs.) of coal distilled. This proportion is nearly at the rate of 1 square yard of purifier for each ton of coal distilled. The calculation is made on the quantity of coal distilled in twenty-four hours, this being the interval at which the lime in the purifiers requires to be renewed.

It is also made on the supposition that the purifiers contain three layers of lime, so that the proportion becomes 3 square yards of screen containing lime for every ton of coal distilled in twenty-four hours. The cover of the purifier is made of light boiler-plate provided with a border or rim which dips into a ring surrounding the purifier, and filled with water, so as to make a perfectly hydraulic joint. The cover is also fitted with handles, by means of which it can be removed when the lime requires to be renewed. The annexed fig. 54 is the section of a dry-lime purifier in its most simple state. *a a a a* are the trays or sieves containing the lime; *b b* is the circular ring containing water for the border of the cover to fit into; *c* is the inlet-pipe passing through the bottom of the purifier, and *d* is the outlet-pipe passing through the cover, and sealed by dipping into a rim of water in the same manner as the cover itself.

Fig. 54.



Another form of dry-lime purifier is frequently used, namely, a rectangle whose length is equal to twice its breadth, with a

division fixed across it in the middle, so that the gas first passes up through the sieves on one side of the division and then down through those on the other side. The outlet-pipe in this case passes off from the bottom without the water seal, which is necessary when it goes off from the moveable cover. The advantage of using more than one purifier is that the lime requires renewal less frequently, and the purification is more perfect, by passing the gas first through the most foul purifier and then into the one which contains the freshest lime. All gas-works, however small, should contain at least two purifiers; and few, however large, contain more than three dry-lime purifiers in a set, there being in the case of large works two sets with three purifiers in each, so that the gas can be passed through one set while the trays are being changed in the other. Another plan is where four purifying vessels are used, three being worked at one time, while the fourth is being prepared and filled with fresh lime ready to take its turn.

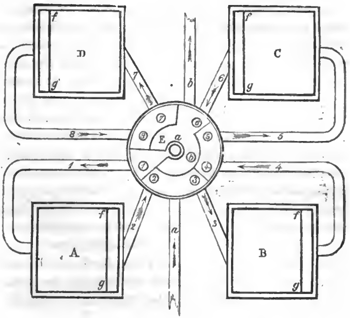
There is probably no part of the gas manufacture where greater ingenuity has been displayed than in the contrivances for changing the gas from one purifier to another. The beautiful modification of the hydraulic valve, by which the gas is collected at its first entry into the purifying machinery and made to traverse certain pipes and perform long evolutions, and at last is discharged in a state of almost perfect purity to take its place in the gas-holder, must ever command the most cordial admiration.

To Mr. Malam, whose name is identified to a great extent with the progress of gas-lighting, we are indebted for a description of purifier which has been adopted in a great number of large works, where it is used at the present day.

This purifier consists of a central valve and cover, and four separate vessels placed at equal distances around it, with contrivances for working the gas through three of the purifiers in succession, while the fourth is being prepared for use. The purifier about to be described is calculated for a gas-works

where the maximum quantity required to be passed through in twenty-four hours does not exceed 200,000 cube feet of gas. In larger works than this it is advisable to have several sets of purifiers instead of enlarging the size of the vessels. In the annexed wood-cut, fig. 55, E is the outer case of the central

Fig. 55.



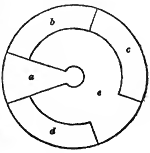
valve, being a cylinder either of cast or wrought iron, about 4 feet 6 inches diameter and 3 feet deep: it is supported on piers of brick-work 2 feet high, and the bottom is perforated with ten round holes to receive the ends of as many pipes leading to and from the four purifiers and also the main inlet and outlet pipes. A, B, C, D, represent the four purifiers, which are each 5 feet square and 3 feet 6 inches deep, supported on brick piers 1 foot high. Each purifier contains seven layers of lime, each layer supported on four trays or sieves about 2 feet 4 inches square. The sieves are either made of strong $\frac{5}{16}$ wires placed $\frac{3}{8}$ths of an inch apart, or are cast plates about

$\frac{3}{8}$ths of an inch in thickness, with open slits $\frac{1}{4}$th of an inch wide and $\frac{1}{4}$th of an inch apart.

The pipes marked 1, 3, 5, and 7 are the inlet-pipes, which admit the gas from the case E to the under side of the purifiers. The pipes marked 2, 4, 6, and 8 are the outlet-pipes, which convey the gas from the purifiers back to the case after it has passed upwards through all the layers and descended at the back of the plate, *fg*, to the bottom of the purifier, where the outlet-pipes are attached. *a* is the main inlet-pipe, which conveys the gas from the washer or the condenser, as the case may be, and *b* is the main outlet-pipe, which takes the gas off to the gas-holder. Each of the purifiers, A, B, C, D, has a cover or lid, with sides and ends 10 inches deep, and these fit into a groove formed all round each of the purifiers, and filled with water so as completely to seal up each of these vessels and prevent the escape of gas. The cylinder E has a peculiar cover, which is of less diameter than E, and fits inside it in such a manner as to open a communication between the pipe *a* and either of the four inlet-pipes 1, 3, 5, or 7, and at the same time to open a communication between one of the outlet-pipes and the pipe *b* which takes off the purified gas.

The vessel E is filled with water to the depth of 10 inches, and each of the ten pipes passes up through the bottom to the depth of 12 inches, so that the mouth of each is 2 inches above the surface of the water. The cover which fits into E is in some cases a casting, and in others is made of plate-iron. It is a cylinder 4 feet 3 inches in diameter, furnished with a top but no bottom. The cylinder, the underside of which is shown in fig. 56, is divided into five partitions, *a*, *b*, *c*, *d*, and *e*; the first of which, *a*, fits over the inlet-pipe *a* in fig. 55, and either of the inlet-pipes leading to the purifiers. The partitions *b*, *c*, and *d* each fit over an inlet and an outlet pipe, each partition opening the communi-

Fig. 56.



cation between a pair of pipes; and the fifth partition, *e*, fits over one outlet-pipe from one purifier and over the pipe *b* leading to the gas-holder. The wood-cut, fig. 56, is a plan showing the under side of the frame or cover which fits into the case E. Fig. 55 shows the frame in such a position as to open a communication between the inlet-pipe *a* and purifier A, and I now propose to trace the progress of the gas from its inlet at *a* till it passes out to the gas-holder. The gas then having arrived in the centre of the case E, fills up the space between the water in E and the cover of the interior frame, and has no means of escape except by passing down the pipe 1, which leads into purifier A, arrived in which it ascends up through the layers of lime and passes over the top of the dividing plate *fg*, and down again on the other side to the bottom of the purifier, when it returns by pipe 2 to the case E. Here it has no means of escape except by the pipe 3, which it accordingly enters, and arrives at the under side of purifier B, which it traverses in the same manner as A, and again returns by pipe 4. The only communication open in the case being that between pipes 4 and 5, the gas proceeds to purifier C and returns by pipe 6, which is shut off from communication with every pipe except *b*, which the gas accordingly enters and proceeds to the gas-holder.

It will be observed that only three purifiers have been worked,—the fourth, D, having been under preparation until required. In order to ascertain when it is time to shift the frame so as throw purifier A out of use and bring D in, the gas is tested at the last purifier, and if found to possess any sign of impurity the frame is shifted so as to bring the triangular division *a* in fig. 56 over pipe 3 in fig. 55. This arrangement will cause B, C, and D to be the three working purifiers, and A to be the one undergoing renewal in readiness for its next turn. When purifier B is made the first in order, the communication is open between pipe 8 and the gas-holder; when C is the first purifier, then pipe 2 is placed in communication with the gas-holder; and when D is the first in order, pipe 4 com-

municates with the gas-holder. A little consideration will show how by the simple shifting of the frame round its centre in succession over each of the four outlet-pipes, each one of the four purifiers is brought into action one after the other, and how the pipe successively communicating with the gas-holder is changed in a corresponding manner. The frame is lifted very simply by means of an upright shaft attached to the top of it; this shaft has a screw cut upon it which works the frame up by turning round a lever with a corresponding thread. A simple contrivance shows in what position the triangular partition is placed, and a few minutes suffice to change the communication from one purifier to another as described.

The preceding account of Malam's purifier is chiefly condensed from Mr. Peckston's Treatise.

Mr. Clegg introduces in his work a dry-lime purifier with a somewhat different arrangement of the purifying vessels and of the hydraulic case, but the principle is much the same as already described. Mr. Clegg's arrangement consists of two sets of purifiers, three in each set. The two sets are about 10 feet apart, ranged parallel to each other, the vessels themselves being 3 feet apart. The gas does not in this arrangement return from each purifying vessel to the hydraulic case, but passes on through each of the three purifiers before it returns. Hence the hydraulic case has only six pipes opening into it, namely, the inlet-pipe from the wash-vessel, the outlet-pipe to the gas-holder, and one inlet and one outlet pipe from each set of purifiers; there is also more simplicity in the working of the dividing frame. The hydraulic case has no top, and the frame is merely a light plate-iron cylinder divided into three equal parts by three plates radiating from the centre, and forming angles of 120° with each other. The dividing frame is only required to be placed in two positions; namely, 1st, to open the communication between the main inlet-pipe and one set of purifiers, at the same time opening the communication between the return-pipe of the same set and the

pipe leading to the gas-holder; and in the 2nd position, shutting off all the last-named communications, and opening corresponding ones with the other set of purifiers. The purifiers are generally changed every twenty-four hours, and at the instant of turning the dividing frame all the communications are open, so that the gas will pass through both purifiers. When the gas is changed from one set of purifiers to the other, the covers of the first set are taken off and all the sieves removed; the sieves from the last purifier are then placed in the first: the lime from the first purifier is quite exhausted, and must either be put aside for sale or to have the sulphur sublimed if this method be practised. The second and third purifiers must be filled with fresh lime, and the covers replaced, while the lime from the second purifier may be spread on the ground, where room can be afforded for the purpose, and in a week or two will be fit for use in the first purifier.

The lime for charging the purifiers should be thoroughly slacked and sifted, to prevent any lumps being used, as no part of the lime is of any use unless reduced to the state of powder. The lime should be spread in a bed or layer about 2½ or 3 inches in depth, and should be of such consistency as not to adhere to or discolour the hand. At some works it is the practice to sprinkle each bed of lime with water from a watering-can, so as to increase the degree of moisture.

COST OF PURIFICATION BY DRY LIME.

At the Imperial Gas-Works in London, 1 bushel of quicklime, which costs *7d.*, purifies 10,000 cubic feet of gas. At Cheltenham 1½ bushel of lime, costing *5d.* to *6d.* per bushel, is required to purify 10,000 cubic feet of gas. At Birmingham, where lias lime is used, the purification by dry lime costs for lime and labour 1¼*d.* to 1½*d.* per thousand feet, without making any deduction for the sale of the refuse lime, which is sold for two-thirds of its original cost; and at Chester, where the car-

boniferous lime of the Flintshire coal-field is used, 1½ cwt. is required to purify 10,000 cubic feet: the price of this lime is 13*s*. 4*d*. per ton, so that the purification of 10,000 feet costs 1*s*. for lime alone.*

In some works the refuse lime is sold for agricultural purposes, being much used in the formation of compost heaps, and occasionally applied as a top dressing. It is very useful as a foundation or substratum for gravel walks, as it prevents the worms from coming up and disfiguring the walks by heaping up those little spiral coils of earth so distasteful to the gardener.

In other works where the spent lime is unsaleable, the sulphur is driven off from the lime by placing it in an old worn-out retort, which is heated to a red heat with breeze and cinders. The sulphur thus produced was at one time a marketable commodity, and during the sulphur monopoly probably yielded a small profit on the expense of manufacture: the profit at the present day is somewhat questionable.

Mr. Croll estimates the expense of lime at £383. 6*s*. 8*d*. for the purification of 368 million cube feet, or at the rate of ¼*d*. per thousand feet. Mr. Barlow makes the cost considerably more; he estimates that to purify this quantity of gas in the wet way,

	£.	s.	d.
817 cube yards of lime would be required, costing	510	2	6
Removal of refuse lime	204	5	0
	£714	7	6

or at the rate of ·46*d*. per thousand feet; in addition to which he estimates the labour of working the purifiers at £374. 10*s*., which would increase the whole cost of purification to nearly ¾*d*. per thousand feet of gas made. In estimating the capacity of dry-lime purifiers, assuming that 25 square feet of surface are required for 10,000 feet of gas, it is evident that where a set of four purifiers is used, the three which are actually always at work should have a surface equal to the purification

* Clegg's Treatise on Coal Gas, 1841.

of the maximum quantity of gas produced in twenty-four hours. Also where a double set of three purifiers is used, each set of three must have a superficial area capable of purifying the maximum production. Thus, if we represent in cubic feet the maximum production of gas in twenty-four hours by p, and call a the total area required for its purification, we have these equations:

$$\frac{10{,}000\,a}{25} = 400\,a = p, \text{ and } \frac{p}{400} = a.$$

As three purifiers are used in each case, $\frac{p}{1200}$ = area of each purifier; if three layers of lime be used, $\frac{p}{3600}$ = area of each layer; if five layers, $\frac{p}{6000}$ = area of each layer; and if seven layers, $\frac{p}{8400}$ = area of each layer. These simple equations will of course have to be adjusted according to the quality of the lime, which will sometimes require to be used in greater quantity than a bushel for 10,000 feet, and a greater extent of surface than 25 feet may sometimes be necessary to effect the purification.

PURIFICATION BY WET LIME.

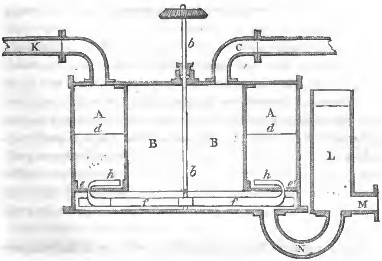
In this process the lime, after being slacked, is mixed with water in the proportion of 48 gallons of the latter to 1 bushel of quick-lime or 2 bushels of the hydrate: it is necessary to mix the lime and water together in a separate vessel, because the fluid lime must be introduced into the purifier in a prepared state; hence the mixing is commonly effected in a large brick or iron cistern placed at a higher level than the purifiers. In the centre of the cistern is fixed an iron shaft carrying at its lower end a stirrer or agitator, something like the contrivance used in the mash-tubs of the great breweries: this constant agitation is necessary in order to keep the lime in mechanical suspension in the water, as the latter does not dissolve the lime nor combine chemically with it. The revo-

lution of the stirrer is effected by the steam engine now used in most gas-works,—a bevelled wheel on the upright shaft gearing into a similar wheel on a horizontal shaft driven by the engine.

In large works it is usual to have two sets of wet-lime purifiers, two purifiers in each set; these are sometimes placed one over the other when economy of space is an object, and at other times are placed side by side: they should always, however, be placed at different levels, as in working them it is usual to empty the contents of one purifier into another.

The wet-lime purifier consists of a cast-iron cylinder entirely closed at top and bottom, except where the inlet and outlet pipes join it, and where an opening is required for charging it with lime-water, which same opening is also used for drawing off the charge. To the inside of the cover of this outer cylinder is bolted an inlet cylinder usually made of wrought-iron plate, either 3 or 4 feet in diameter. This inlet cylinder has no bottom, and reaches to within a foot from the bottom of the outer cylinder, but has bolted to its bottom flange a wide ring or dash plate of sheet-iron, whose outer diameter is only 8 or 9 inches less than that of the outer cylinder, so that a space of only 4 or 5 inches is left between the outside of the ring and the interior of the large cylinder. These particulars will be more fully understood from the wood-cut, fig. 57, to which reference is now made. A is the outer cylinder and B the inlet cylinder, into which the pipe C opens to admit the gas from the condenser. The gas passes down through the inlet cylinder B, and when the pressure becomes sufficient forces its way up through the fluid lime, the surface of which, *d d*, is 8 or 9 inches above the dash plate attached to B: *e* is a hoop of angle-iron attached by bolts to the inside of the purifier, of such a diameter as to allow only half an inch of space to intervene between it and the iron dash plate attached to B. The bottom of the angle-iron hoop is on a level with the dash plate, so that the gas has to find its way through the small space between them: *f* is the revolving arm or stirrer

Fig. 57.



keyed on to the shaft *b*, which works in a bearing fixed on the bottom of the purifier, and passes through a stuffing-box in the lid, being worked by a bevel-wheel as already described for the mixing vessel. To the main arm is attached a band of bent wrought iron, *h h*, which continues up through the small opening already spoken of, and laps over the dash plate till it nearly touches the inlet cylinder, the object of this being to keep up the agitation and prevent the solid particles of the lime from settling; it also keeps the half-inch opening clear and free for the gas to pass through. K is the outlet-pipe for the purified gas after it has passed through the water, and reached the annular space between the outer and inner cylinders. L is an outside chamber, and M an outlet-pipe connected with the purifier by a siphon-pipe N; the pipe M is provided with a valve, which is kept closed, except when the contents of the purifier are to be drawn off. The lime-water is brought into the purifier through the chamber L, and when it is required to empty the purifier, the valve in M is opened. As the siphon-pipe N must always remain filled with fluid, it

is evident that no gas can escape when the lime-water is drawn off. This arrangement is necessary, as when wet-lime purifiers were first used, a serious explosion occurred from the escape of gas along with the spent lime-water. The wet-lime purifiers are variously worked; when four are used, two vessels are worked at one time, and when the lime in the first is expended, it is cut off, and the second and third are worked, and so on in succession. Sometimes these purifiers are worked one over the other, and when the water in the lower vessel has become so impure as to cause the gas issuing from the last purifier to colour the test-paper, the water is let off from the lower purifier, and that from the second allowed to flow into it. The water from the third purifier is also discharged into the second, and the upper or third purifier is charged with fresh lime-water.

The quantity of lime required for purifying in the wet way is said by Mr. Clegg to be about the same as for the dry purifiers,—namely, in London about one bushel of quick-lime for 10,000 cubic feet of gas: this when diluted with 48 gallons of water will occupy 9 cubic feet, from which the capacity of a purifier sufficient for any given production of gas may readily be computed. The head of water through which the gas passes in the purifier need not exceed 8 or 9 inches. An area of 9 square feet in the purifier will be sufficient for 10,000 cubic feet of gas. Where the gas is passed through two vessels in succession, half this area will be sufficient for each, or at the rate of $4\frac{1}{2}$ square feet for every 10,000 feet of gas passed through in twenty-four hours. Let a be the area of the purifier in square feet, and n the number of purifiers employed, then $\frac{10.000\, a\, n}{9} = q$, the quantity of gas in cubic feet that will be purified: if q be given, then $\frac{9\, q}{10{,}000\, n} = a$, the area of each purifier in square feet. The purifying apparatus proposed by Mr. Croll for the Central Gas Consumers' Company, at the time when the production of gas was estimated at 368 million feet per annum, or 1,800,000 feet as a maximum in twenty-

four hours, consisted of 8 wet-lime purifiers, each of 15 feet diameter, and two dry-lime purifiers, each 12 feet square and 7 feet deep. The following is the estimate for these purifiers as furnished by Mr. Croll in his evidence before the House of Commons:

Purifiers.

	Tons	cwt.	qrs.	lbs.	£.	s.	d.
Eight purifiers, 15 feet diameter by 3 feet 6 inches, containing 4700 feet, ⅝ inch thick, at 28 lbs. per foot . . .	48	5	0	22			
Two dry-lime purifiers, 12 feet square by 7 feet, containing 1066 feet, ⅝ inch thick, at 23 lbs. per foot . . .	10	18	3	18			
Beams and columns to support ditto .	12	0	0	0			
	71	4	0	12			
71 tons 4 cwt. of cast iron, at £10 per ton					712	0	0
3050 bolts for ditto, at 0·73 lbs. each, 2226 lbs. at 4*d*. .					37	2	0
	Tons	cwt.	qrs.	lbs.			
Dash plates of 8 purifiers, measuring 14 feet diameter, each 1232 square feet, at 10 lbs. per foot . . .	5	10	0	0			
Supporting beam, cylinder, and rods, complete	3	0	2	0			
Agitators, in all	0	10	0	0			
138 feet of shafting from steam engine	0	12	1	8			
Dry-lime purifier covers complete .	1	10	0	0			
128 sieves in dry-lime purifiers, at 74 lbs. each	4	4	2	8			
	15	7	1	16			
15 tons 7 cwt. 1 qr. of wrought iron, at £24 per ton .					368	14	0
					£1117	16	0

Mr. Barlow, in his Report, makes no objection to this estimate, and in fact sanctions it by adopting it as part of his own estimate. Mr. Barlow differs very widely from Mr. Clegg, however, in fixing the quantity of lime for purification; as he states that a bushel of unslacked lime used in the wet-lime purifiers will purify 25,000 feet of gas, whereas Mr. Clegg says a bushel will be required for 10,000 cubic feet.

The following year, when the estimated production was reduced to 320 million feet per annum, and the maximum daily production to 1,500,000 feet, the contract entered into with Messrs. Rigby comprised the erection of four wet-lime purifiers, each of 15 feet diameter, and two dry-lime purifiers, each 12 feet square, with four layers of lime in each.

	Cube feet.
The total area of the two dry-lime purifiers would be 1152 square feet, and allowing 25 square feet to purify 10,000 cube feet of gas, their performance would be $\frac{1152 \times 10,000}{25} =$ . .	460,800
The area of the four wet-lime purifiers would be 708 square feet, which, at 9 feet area for 10,000 cube feet of gas, gives $\frac{708 \times 10,000}{9} =$	786,666
	1,247,466

making the whole purifying power of the establishment equal to something less than a million and a quarter feet in twenty-four hours; but this calculation is founded on Mr. Clegg's estimate of a bushel of lime for 10,000 feet, which is undoubtedly too high.

The following is the specification for these purifiers as laid before the Committee by Mr. Croll:

Wet-Lime Purifiers.

Purifiers to be 15 feet diameter, by 3 feet deep inside measure, constructed as follows, viz.:

Top and bottom plates to consist each of a centre plate and ten other plates radiating round it. *The centre plate* to be 5 feet 1 inch in diameter, with a 3-inch flange round the circumference, supported by fillets 6 inches apart, and to have six ribs cast upon it 4 inches deep where they terminate round the inlet pipe, and 2 inches deep where they finish at the outside flange; the flanges and the strengthening ribs to be on the outside. One half in number of these centre plates, which will form the bottom to each, have a shoe cast on its centre in the inside, and a proper socket in its centre to receive the lower end of the agitating shaft.

The other half in number of these plates, which will form the centre of the top, each to have a 14-inch flange inlet cast in its centre 5 inches high, with $2\frac{1}{2}$-inch flange, and six bolt-holes.

Radiating plates.—Twenty in number to each purifier, to radiate round the centre plates, forming with them a circle 15 feet 6 inches in diameter; each plate to have a rib up its centre on the outside, 2 inches high at the inner end, diminishing to the surface of the plate at the circumference. One of the radiating plates to each purifier to have a 14-inch flange outlet cast upon its outer surface, standing 5 inches high, flange $2\frac{1}{2}$ inches broad, with 6 bolt-holes. The centre of this outlet to stand 1 foot 1 inch from the inner end of the plate; the plate to have a 3-inch flange on three sides.

Side plates to be ten in number to each purifier, 3 feet deep, and flanges all round the plate $2\frac{1}{2}$ inches broad on the outside, with proper strengthening fillets, one between each bolt-hole, 6 inches apart; a small ornamented strengthening bead to be cast upon the outside of the plate. Two of these plates in each purifier to have two brackets cast on their inner surface; their upper surface, upon which a beam will rest, to be 1 foot 6 inches from the top side of the plate, for the purpose of supporting two cast-iron beams to support centre inlet cylinder, and 3 feet 2 inches apart, centre to centre.

Inlet cylinder to be 3 feet inside diameter, made of $\frac{1}{4}$-inch wrought-iron plates 2 feet deep, with a $2\frac{1}{2}$-inch flange round each end; the one to bolt to the crown plate, the other to bolt the dash plate to.

This cylinder to have snuggs riveted on it, which will rest on the beams that are to be supported on the snuggs cast on the side plates.

Beams which support cylinder.—Two to each purifier, to be 14 feet 7 inches long, 6 inches deep at the centre, diminishing to 4 inches deep at each end, and $1\frac{1}{2}$ inch thick, with holes for bolting on the short cross-beams to; these beams to be 3 feet long, 6 inches broad, and 1 inch thick, return ends.

Dash plate to be 14 feet 4 inches diameter, made of ¼-inch boiler plate, with a 3-feet hole cut in its centre; this plate bolted to the inlet cylinder with ½-inch bolts 9 inches apart, all round the cylinder, and likewise supported by 1-inch angle iron suspending rods from the roof; the circumference kneed at each end, and fastened with two ½-inch bolts; a ring of sheet iron ⅛th of an inch thick and 12 inches broad, and kneed, to be fastened to the side plates by ½-inch bolts, 1 foot apart, so that the under side of it will be on a level with the top side of the revolving arm.

Revolving arm to be 14 feet 9 inches long, 4 inches broad, and ⅝ of an inch thick, set at an angle so that it will give a revolving resistance of 2 inches only, and to be supported at each end by a 6-inch roller of cast iron, made fast to it by proper wrought-iron supports; a bent arm to be bolted to the main arm, and to bend up and over the dash plate, extending over it 2 feet 6 inches, and to revolve at a height of 2 inches above the dash plate.

This arm to be made fast to the upright spindle by six ¾-inch bolts; the spindle by which it will be turned to be of wrought iron, 2 inches in diameter and 8 feet long, with a square shoulder at each end, one to receive a bevel-wheel, the other to receive the revolving arm.

Side cylinder and bottom bend to be a cylinder 1 foot 5 inches diameter by 4 feet deep, open at the top, and an 8-inch hole in the centre of the bottom; the bend to be a double flange, 8-inch bend, measuring 2 feet 6 inches to the top side of the bend, made fast to the purifier and side cylinder by ten ½-inch bolts.

Conclusion.—The top and bottom plates to be ⅝ths of an inch thick, the side plates to be ½ an inch in thickness, the strengthening ribs and flanges to be of the same thickness as the plates, the bolt-holes to be 6 inches apart, centre to centre; the whole of the plates to be of the best sound cast iron, geometrically true, and fastened together by ⅝ bolts, with well put in iron cement joints, and the whole to be perfectly water-tight.

Dry-Lime Purifiers.

The dry-lime purifiers to be constructed as follows:

Bottom plates, sixteen in number, so that when joined together they will be 12 feet square, $\frac{5}{8}$ths thick, with flange all round, $2\frac{3}{4}$ inches broad, clear of the plate; all firmly bolted together by $\frac{5}{8}$th bolts, 6 inches apart, centre to centre; with strengthening brackets, one between every two holes. One of the bottom plates to have a hole in it 14 inches in diameter, with a cover plate standing 9 inches high, and 24 inches in diameter, made fast over the hole by six 15-inch bolts, with a collar 3 inches from each end, the one to rest upon the bottom, the other to support the cover plate, and made fast at each end to the cover plate and bottom plate by a $\frac{5}{8}$th nut screwed on each end of the bolt. One bottom plate to have a hole 12 inches in diameter, with ears, lid, and cross-bar, the same as a retort mouth-piece, for the purpose of opening from beneath as a discharge hole.

Side plates.—One to bolt on to the bottom plates and stand, 4 feet 2 inches deep on the inside of the purifier, sixteen plates to form the sides, having a water lute cast on, 8 inches broad, 1 foot 6 inches deep inside all round these plates, to be $\frac{5}{8}$ths thick, with flanges $2\frac{3}{4}$ inches broad clear of the plate; the whole to have fillets between every two holes, being 6 inches apart, centre to centre.

Two side plates in each purifier to have a flange outlet 14 inches diameter cast on, standing out 9 inches; the flange to be $2\frac{3}{4}$ inches clear of the pipes; the bottom of the pipe on the inside to be on a level with the bottom of the purifier.

On the inside of this plate will be cast two flanges standing the whole height of the plate, $2\frac{1}{2}$ inches broad, and 14 inches between them; these flanges to have $\frac{3}{4}$ holes in them every 9 inches in height, for the purpose of receiving bolts to fasten on the outlet box.

Outlet box to be 4 feet deep by 12 inches square, with a $2\frac{1}{2}$-inch flange at the bottom for bolting it to the bottom

of the purifier; the bolts to be $\frac{5}{8}$ths in diameter and 6 inches apart, centre to centre.

Snuggs to be cast on the side plates at the respective heights marked on the drawing, for the purpose of resting a tee-iron into, upon which the trays will rest, projecting 4 inches and 6 inches deep; twenty bars of 4-inch tee-iron, each 12 feet long, to rest into the snuggs cast upon the inside of the side plates, and not to be fixed by any bolting.

Trays to be four in number to each purifier in squares of 3 feet by 3 feet, making sixteen squares to each tray; these squares to be formed of 2-inch flat bar iron half an inch thick as an outside frame, with two $\frac{1}{2}$-inch cross-rods; this frame to be fitted in with $\frac{1}{2}$-inch round rod with $\frac{1}{2}$-inch spaces between, properly riveted at each end through the framing, with counter-sunk heads.

Cover to be constructed of a square frame of 3-inch angle iron 12 feet 10 inches on the side, with a square frame of 3-inch flat bar iron in the centre, 4 feet on the side; these two frames to be joined by 3-inch tee-iron bracing, made fast with $\frac{1}{2}$-inch rivets. Eight 1-inch eye-bolts with collar above the screw to be passed through the angle iron, and made fast by a nut on the inside for the purpose of lifting it by. This skeleton to be covered with sheet iron $\frac{1}{8}$th of an inch thick with $1\frac{1}{2}$-inch lap, inlaid with twine saturated in red-lead, and made fast with $\frac{3}{8}$th rose-headed rivets $1\frac{1}{2}$ inch apart, centre to centre; the plates on the top to lap on the angle iron 2 inches, and be made fast to it with $\frac{1}{2}$-inch rivets, $1\frac{1}{2}$ inch apart, centre to centre; the sides to be $\frac{3}{16}$ths in thickness and lapping on the angle iron to the same depth, and riveted with the same sized rivets.

A binding rim of $1\frac{1}{2}$-inch half-round iron to be fastened to the outside of the side at the bottom, by $\frac{1}{2}$-inch rivets, 6 inches apart.

A water lute, 16 inches deep and 6 inches wide, to be constructed on the top of the lid.

The whole of the above work to be of the best iron used for

such purposes, free from cracks or flaws, and geometrically true; the bolts to be all properly lapped with hempen washers saturated in red-lead, and good strong threads cut in them; the joints to be made of good clean iron cement firmly caulked in.

The plates of the cover to receive a coat of red-lead at the joinings on the inside, and two coats all over on the outside, and the whole to be made perfectly gas-tight, fitted up complete, and guaranteed for twelve months.

Tender to be for two purifiers.

Four Wet-Lime Purifiers.

CAST IRON.

	Tons	cwt.	qrs.	lbs.
Bottom plates	2	11	3	26
Side plates	1	11	2	13
Top plates	2	13	0	13
Side cylinder	0	7	3	18
Beams to support inlet cylinder	0	7	1	8
	7	11	3	22
				4
Four purifiers	30	7	3	4

WROUGHT IRON.

	Tons	cwt.	qrs.	lbs.
Dash plate, with suspending rods, complete .	0	19	1	13
Inlet cylinder	0	2	3	16
Revolving arm, rollers, and spindles, complete .	0	3	1	13
	1	5	2	14
				4
Four purifiers	5	2	2	0
Bolts and rivets in all	0	5	0	18
				4
Four purifiers	1	0	2	16

Two Dry-Lime Purifiers.

CAST IRON.

	Tons	cwt.	qrs.	lbs.
Bottom plates, flanges, and fillets, complete .	2	1	2	21
Side plates, ditto, ditto .	4	9	0	1
Two outlet boxes	0	5	1	19
	6	16	0	13

WROUGHT IRON.

Tee-iron beams to support sieves . . .	1	6	2	17
Sixty-four sieves	3	4	3	12
Cover, framing, and bolts, complete . .	1	3	0	2
Cleaning lid, cross-bar, ears, and screw . .	0	0	3	18
Bolts and rivets in all	0	4	1	4
	5	19	2	25
Add cast iron as above . . .	6	16	0	13
	12	15	3	10
Total estimated weight of two purifiers . .	25	11	2	20

It has been stated that Mr. Barlow estimates one bushel of lime for purifying 25,000 cubic feet of gas. At the Phœnix Works half a bushel of lime is used in the wet-lime purifiers per ton of coal carbonized, or at the rate of a bushel of lime for purifying from 18,000 to 20,000 feet of gas.

Mr. Clegg has fallen into some error in speaking of the qualities of lime best adapted for purification. He rightly gives the preference to that made from the purest limestones, and then observes that the purest lime is obtained from the lias limestones and the lower oolite. Now this is contrary to all received experience, and analysis always shows that the lias limestones, both the white and blue varieties, contain a large per-centage both of alumina and silex. Many of the lias limestones contain as high a per-centage of these foreign ingredients as the septaria or cement stones, and are, like the septaria, mere argillaceous carbonates of lime. It is, in fact, this union of clay and lime in the same stone which gives to the lias lime

its peculiar and valuable hydraulic properties of setting under water, and of setting under all circumstances much more rapidly than the fat or pure limes. The same remarks as to impurity apply in some degree to the lower oolitic limestones, which are all more or less impure, and not nearly so well fitted for the purification of coal gas as the weak chalk limes. I venture to submit the following classification of the best-known limestones of this country, in the order of their purity, and which order also expresses their value for the purpose of purifying gas.

1. The white chalk limestone of Merstham, Dorking, Charlton, Erith, and other parts of the chalk range surrounding the metropolis.

2. The grey chalk limestone, from the lower beds of chalk.

3. The blue beds of the upper and middle oolites.

4. The lower, white, and grey limestones of the oolites.

5. The most calcareous and crystalline beds of the carboniferous or mountain limestones, colours grey and bluish.

6. The magnesian limestone of Yorkshire and Derbyshire.

7. The white lias limestone.

8. The blue lias limestone.

9. The Silurian limestones of Wenlock, Dudley, &c., and the coralline limestones of Plymouth and the neighbourhood.

In passing the gas through a succession of either wet or dry lime purifiers, it is important to be able to test the quality of the gas at each stage of the manufacture, in order to determine whether the purifiers are acting properly, to afford a check on the quality of coal used, and to determine when it is necessary to turn off one of the purifiers and bring another one into work with a charge of fresh lime. The most delicate test for sulphuretted hydrogen is a solution of nitrate of silver in distilled water, made by adding 4 grains of nitrate of silver to 2 ounces of distilled water. The test, however, most commonly used is acetate of lead, made by adding to distilled water as much acetate of lead as it will dissolve. The solution so made may be spread over the surface of a sheet of writing-

paper with a camel-hair pencil, and when paper so prepared is applied, while the solution is still wet, to a small stream of gas, the shade of colour produced indicates the degree of purity in the gas. In many works each of the purifiers is provided with a stop-cock and a very small single jet burner, so that on turning the stop-cock a minute stream of gas will issue, sufficient to show its quality by the application of the test-paper. The pipe leading into the first purifier is furnished with a similar stop-cock, from which issues, when required, the crude gas before purification. If the test-paper be held for a few seconds in front of the small stream of crude gas, the paper will be instantly blackened, owing to the acid having a greater affinity for the sulphur in the gas, and parting with the lead in solution, which consequently appears in the metallic state of minute division on the surface of the paper. On applying a fresh surface of the test-paper to the gas from the first purifier, the dark shade is not so intense, as there is less sulphur to combine with the acid, and consequently less of the lead is set free. The gas from the second purifier ought to give only a slight shade of colour, while that from the third and last purifier should produce no shade whatever, as it should contain no sulphuretted hydrogen, and therefore produce no decomposition of the acetate of lead. Mr. Clegg recommends that test-paper should be applied every morning to the four descriptions of gas, namely, the crude gas and to that from each of the three purifiers, and that test-papers should be printed with squares for each kind of gas. The squares should be painted with the solution of acetate of lead immediately before its application to the jet of gas, and the papers preserved as a record of its purity from day to day. Where nitrate of silver is used as a test, the shades of colour are produced by a similar decomposition, the metallic silver being in this case deposited on the surface of the paper. The phial in which the nitrate of silver is kept should be coated with tin-foil to preserve it from the action of light, which turns the solution black, and if the test-papers are to be preserved, they

must for the same reason be kept between the leaves of a book, or otherwise excluded from the light.

MR. LAMING'S PROCESS OF PURIFICATION.

A method of purifying gas, recently patented by Mr. Richard Laming, and which is being tried by several of the large Gas Companies, will now claim our attention.

This gentleman professes to proceed in a manner analogous to that in which the circulating fluids of the human body are purified. He observes, that the blood in circulating through every part of the system absorbs and carries to the various excretory organs certain superfluous quantities of organic matter, which are required to be expelled from the body. For example, the blood delivers over to the kidneys the two elements of ammonia and those of various acids; and it conveys to the lungs a quantity of carbon, which is there brought into contact with the inspired atmospheric air, and combining with its oxygen is expired in the form of carbonic acid. The blood thus purified from its carbon is again propelled by the action of the heart to the remotest parts of the body, and again becoming loaded with impurities, discharges them by means of the excretory organs, and so the alternate process goes on during the whole period of animal existence.

Mr. Laming practises a somewhat analogous process, by passing the gas through a material which absorbs both its carbonic acid and its sulphuretted hydrogen; and the compounds so formed, when again exposed to the atmosphere, so as to combine with more oxygen, are again converted into a material fit for purification, and may thus be used over and over again in the purifying vessels.

It has long been known, that when gas is passed through ordinary quick-lime, (in chemical language C A O,) that the carbonic acid combines with the lime, and forms carbonate of lime. It is also known, that when gas is passed through either of the sesquioxides of iron, the sulphuretted hydrogen

is decomposed, some of the sulphur combining with the iron and forming sulphuret of iron. Now Mr. Laming, in his method of purification, mixes the quick-lime with the oxide of iron, diffusing the whole through saw-dust or breeze, and hence obtains in his purifying vessel the double compound of carbonate of lime and sulphuret of iron. When this compound is formed, the covers of the purifiers are removed, and the mixture exposed to the oxygen of the air, when the following effects take place. 1st. The carbonic acid having a very feeble affinity for the lime quits it, and combining with the iron and with another atom of oxygen forms *carbonate of iron*. 2ndly. The sulphur leaves the sulphuret of iron, and combining with oxygen to form sulphuric acid unites with the lime, and becomes ordinary *sulphate of lime*. The carbonic acid very soon passes off from the carbonate of iron, which becomes again the oxide, while the sulphate of lime remains unchanged. The sulphate of lime and the oxide of iron are then again placed in the purifiers, and the same changes take place when the gas again passes through the mixture. It will be observed from this description, that the new and important addition which has been made is that of the sulphuric acid, which is formed from the sulphur of the gas combined with the oxygen of the atmosphere. Mr. Laming however observes, that instead of waiting for this spontaneous formation of sulphuric acid, it may advantageously be added at the beginning of the operation, or its place may be temporarily supplied by any other acid which is capable of combining with lime, and of being separated from it at ordinary temperatures by carbonate of ammonia.

The principle then of Mr. Laming's purification is the use of sulphate of lime in a state of intimate combination with oxide of iron. Mr. Laming states that muriate of lime, when it can be conveniently procured, will do equally well with the sulphate.

The inventor sums up the account of his process by

describing it as based upon a certain set of known affinities, by the influence of which the greatest impurity of the gas, namely, its sulphur, is converted into sulphuric acid, and then combined with the next greatest impurity, namely, the ammonia; while the carbonic acid, which is inodorous, is made to escape into the atmosphere, and is thus got rid of without expense.

In this mode of purification the sulphate of lime is decomposed by the ammonia of the gas, and converted into sulphate of ammonia, which salt accumulates in the mass of used material till it becomes inconvenient, when it is removed by solution. Mr. Laming states in conclusion, that his process also removes from the gas its cyanogen and its sulphuret of carbon, which latter is a very injurious compound, and has hitherto very much retarded the admission of gas into private dwellings. The inventor also attributes an excellent effect to the suppression of lime, which is supposed to injure the illuminating powers of coal gas by its alkaline re-action on the hydrocarbons.

Mr. Laming's process of purification is extensively employed at the Chartered Company's Works and elsewhere, one great advantage being that the old dry-lime purifiers can be used for the new process with little or no alteration.

The mixture used at the Chartered Company's Works is made in a cheap and efficient manner by precipitating iron from the solution of sulphate of iron by means of chalk. The matter precipitated consists of a mixture of sulphate of lime with the carbonate of iron, but the carbonic acid soon leaves the iron, which remains as peroxide.

When this mixture is placed in the purifiers, and the gas containing carbonic acid, sulphuretted hydrogen, and ammonia is passed through it, a double re-action takes place,—the sulphur of the sulphuretted hydrogen combining with the iron and forming sulphuret of that metal, while the sulphate of lime is decomposed by the ammonia, carbonate of lime and sulphate of ammonia being formed. On exposing the carbon-

ate of lime and the sulphuret of iron to the oxygen of the air for two or three days, carbonic acid is given off in considerable quantities, the iron becomes again the oxide, and the lime becomes again the sulphate of lime, and the mixture may be used over again.

As the sulphur does not pass off during the exposure to the air, but merely changes its mode of combination, there is obviously a limit to the repeated use of the mixture in the purifiers unless the formation each time of sulphate of ammonia takes up all the sulphur contained in the gas. On this point we are not sufficiently informed, and, in fact, the whole subject demands a more extended inquiry.

The process is undoubtedly one of extreme ingenuity, and besides its employment at the Chartered Works, a modification of it, founded on a patent taken out by Mr. Hills, is used by the Imperial Gas Company. Mr. Hills is said to supply the material under the name of a waste product in copper-smelting, and after use in the purifiers the mixture is oxidized by exposure to the air, as in Mr. Laming's process, and is again and again used for purifying.

At the Western Gas-Works an experiment is being tried at this time for the separation of ammonia in the dry-lime purifiers. A solution is made by adding about 60 gallons of water to a bushel of sulphate of iron in the state of green copperas; the solution being well mixed with saw-dust, which in this saturated state is spread on trays in the dry-lime purifier. The action of ammonia here again is to separate the sulphuric acid from the iron and to form sulphate of ammonia, as in Mr. Laming's process. When the contents of the purifiers are exposed to the air, the iron becomes an oxide, and the mixture may be used over again in the purifiers.

The whole subject of purification is at the present moment in an unsettled state. The more general diffusion of chemical knowledge and the application of chemistry to the useful arts have not failed to influence the operations of gas manufacturers. As a result of this, a great variety of proposals have

been advanced during late years, with the view of improving the system of separating the impurities of coal gas. In addition to those of Mr. Croll, Mr. Laming, and others, which have been described at some length, may be mentioned the proposal of Professor Graham, to add to the hydrate of lime an equivalent of hydrous sulphate of soda. The action of absorbing sulphuretted hydrogen would be much more energetic in this mixture, and would continue, according to the Professor, till two equivalents of sulphuric acid are absorbed by one equivalent of lime. The sulphurets might afterwards be separated from the mixture so used, and its value to commerce preserved by still procuring from it the carbonate of soda.

M. Penot's recommendation of sulphate of lead for separating sulphuretted hydrogen has been already alluded to (see page 32). This process would not supersede the necessity of employing lime and other means to separate carbonic acid and salts of ammonia.

Latterly M. Mallet of St. Quentin has proposed as a purifying medium a residual product which arises in the manufacture of chloride of lime. This product is a combination of chloride of manganese with sulphate of soda. This method is practised at the Gas-Works of St. Quentin, where the material from the purifiers is afterwards operated on for the production of muriate of ammonia. There is a great resemblance between this process and that adopted by Mr. Croll.

CHAPTER XIV.

ON THE GAS-HOLDERS AND OTHER APPARATUS CONNECTED WITH THE STORING AND DISTRIBUTION OF GAS.

The next subject for consideration is that of the gas-holders, or vessels in which the gas is stored ready for delivery into the mains which distribute it throughout the districts to be lighted. These vessels were originally termed Gasometers, which name

is sometimes even now applied to them, but as they have nothing whatever to do with the measurement of the gas, but are mere vessels of capacity, the simple name of Gas-holder appears more expressive and appropriate.

The earliest gas-holders were made in the form of cubes and other rectangular figures, but there were disadvantages in this form, independently of the waste of material required to construct a rectangular figure as compared with that required for a circular figure of the same capacity. The corners and angles of the square figures were also found to require bracing, and other precautions were necessary in order to render the resistance uniform. Wooden tanks were also at one time made for the lifting part of the gas-holder to work in, but this was at a time when gas-holders scarcely exceeded in size some of the large vats or backs in use at the great porter breweries. The construction of these wooden tanks was in fact intrusted to the back-makers, who used to guarantee the duration of the vessel for some period of time agreed on. They were, in consequence, generally constructed in a substantial manner, but it is evident that the rapid increase which took place in the size of gas-holders required the adoption of a different material from wood. When a deputation from the Royal Society, with Sir Joseph Banks at its head, visited the Gas-Works of the Chartered Company in Westminster about the year 1814, they strongly recommended government to restrict the Company from constructing gas-holders exceeding 6000 feet in capacity, to be confined in very strong buildings. When Mr. Clegg published his work in 1841, he says, "gas-holders are now constructed to contain 250,000 feet." In the present year all the new gas-holders of the Great Central Gas Consumers' Company contain 412,000 feet, and there is one in Philadelphia 140 feet diameter and 70 feet high, capable of containing more than a million cubic feet.

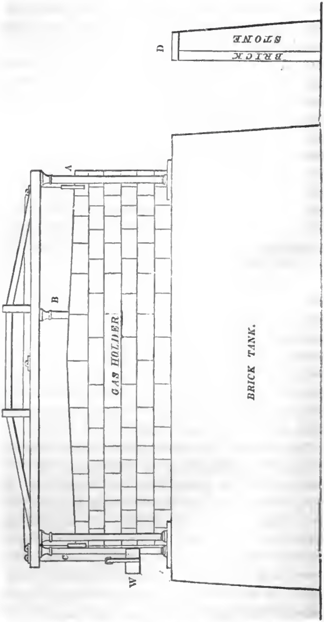
The modern gas-holder is a cylinder of plate iron made of sufficient capacity to contain the maximum quantity of gas produced in twenty-four hours; and in very large works, where

several gas-holders are used, the joint capacity of all the gas-holders should be equal to this maximum production. In many gas-works the capacity of the gas-holders somewhat exceeds the consumption of the longest night, but it is believed that this excess in capacity is unnecessary. The cylinder which contains the gas has no bottom, or it may be described as a cylinder inverted over a cistern of water, both the inlet and outlet pipes having their orifices above the surface of the water, so that the gas is hermetically sealed up within the holder, and can only escape through the outlet-pipe. The mode in which gas is stored in the gas-holder bears a very exact analogy to the mode of collecting and storing gas pursued by the chemist in the laboratory, where the jar to be filled is inverted over a trough containing water, and the gas admitted into it by a bent pipe passing up through the water. In the chemist's method, the jar or gas-holder remains fixed, however, while the water is displaced by the gas: in the gas manufactory, on the other hand, the water is not displaced, but the gas-holder is raised by the gas flowing in.

The principle of sealing up the gas by a water lute or hydraulic joint is, however, the same in both cases, and affords another instance of those beautiful contrivances for using one fluid in the management and manipulation of another which is much lighter and more elastic.

Fig. 58, drawn on a scale of 1 inch = 15 feet, is an elevation of a single-lift gas-holder from the Philadelphia Gas-Works. The lifting part of this gas-holder is 50 feet diameter and 35 feet high, and therefore capable of containing nearly 70,000 cubic feet of gas. A, B, C, are cast-iron columns standing on the brick-work of the tank at three equidistant points. The columns A and C support a trussed frame-work of timber, as shown in the engraving. A similar frame-work extends from B to C, at which latter point the two frames converge. A strong chain is attached to the gas-holder at each of the points A and B, these chains passing over rollers and converging to C, where a chain is also attached to the gas-holder. The chains

Fig. 58.



from each of the three points of suspension thus meeting at c are united into one chain, from which a weight w is suspended

to counterbalance the weight of the gas-holder. D is a section of the tank-wall, showing the outer part composed of stone backing, while the inside is faced with brick.

The telescopic gas-holder, in which the lifting part is made in two separate cylinders, is only an extension of the simple holder rising in one piece.

The upper cylinder is of less diameter than the lower, and is joined to it by a most ingenious contrivance, which also forms a most perfect seal or water lute, as will be presently described.

In the early period of gas-lighting, the gas-holder was suspended in its tank, and invariably counterbalanced by weights which were found necessary to relieve the gas from the great pressure caused by the lifting part of the gas-holder itself. The gas-holder was then made unnecessarily strong and heavy, so that the pressure on the gas would have been far too great without the action of the counterbalance. This pressure on the gas also increased as the gas-holder rose out of its tank, and when the whole of the gas-holder was out of the water and hanging in air (with the exception of the water seal), the weight was of course greatest, and the pressure on the gas at a maximum. This pressure gave rise to great inconveniences, and required a constant attention to the counterbalancing weights where anything like regularity was sought.

Many attempts have been made to regulate the pressure of the holder so as to relieve the gas when flowing in from any pressure whatever, and to restore the required pressure when the gas-holder is full, and the gas has to be forced out through the mains or into other gas-holders. Attempts to effect this regulation of the pressure have been made by means of shifting counterbalances and other contrivances, and patents have been taken out by Malam, Outhot, Parks, Broadmeadow, Macrae, and others, but in no case has the object been properly effected.

The introduction of the governor or regulating machine, which, acting quite independently of the gas-holders, admits

the gas into the mains at a uniform pressure, put an end however to irregularity of pressure as respects the mains, and rendered all attempts to regulate the pressure of the gas-holder unnecessary as far as the mains are concerned.

It may be observed in passing, that notwithstanding the great advantage of the governor, there are many large gas-works in provincial towns which yet do not possess one. Where large factories are supplied from such works, it is a frequent complaint, that for several hours in the evening they cannot obtain a sufficient quantity of light. This grievance, perhaps, even more than the high price charged for gas, has led to the establishment in most large towns of many private establishments for the manufacture of gas on the premises. Generally speaking, the existence of such small independent establishments reflects great scandal on the Gas Company, which with all its appliances, its large joint-stock capital, and the presumed superior skill of its management, cannot control the custom of individual manufacturers, who prefer for some reason or other to make gas for themselves, notwithstanding numerous undeniable disadvantages of making it on a small scale. Wherever the small rival establishments have originated in a defective supply of gas at the time when it is most required, this may generally be traced to the absence of a governor at the principal works, and a consequent attempt to regulate the pressure by means of the gas-holder and its weights. Supposing the gas-holders to contain an ample supply of gas, which after leaving them is passed through a governor at a regular and constant pressure, the quantity of light given by all the burners will be constant and uniform whether the consumption be large or small, and will also be quite independent of the weights of the gas-holders and the effect of their counterbalances.

The tanks of gas-holders are usually made of brick masonry, or of iron. Of late years a good many iron tanks have been constructed, but notwithstanding the low price of iron they are still considerably more expensive than brick, while in the

largest modern example which we have in this country, namely, the Works of the Great Central Gas Consumers' Company, just erected at Bow Common, all the gas-holder tanks are of brick.

When the tank is made of iron, the pieces of which it is composed are usually cast in plates about 5 feet long and 3 feet in depth. The plates have flanges all round them, usually 2 inches to $2\frac{1}{2}$ inches deep, and $\frac{3}{4}$ of an inch thick. The flanges are cast with holes about 10 or 12 inches apart to receive the bolts used for fixing the plates together. The plates are further strengthened by diagonal ribs $\frac{1}{2}$ an inch thick, 2 inches deep in the centre, and diminishing to nothing at the corners of the plate. The thickness of the plates varies from $1\frac{1}{4}$ inch for the bottom row of plates, down to $\frac{5}{8}$ths of an inch for the top row of plates. The plates are put together in the usual way with bolts, nuts, and iron cement, the joints between each row of plates falling in the middle of the plate above and below, according to the system termed breaking joint in bricklaying and masonry. The plates for the bottom of the tank are usually $\frac{3}{4}$ of an inch in thickness. Iron tanks are made of various sizes up to 100 feet in diameter, but seldom more than 25 feet deep. The introduction of tanks or cisterns formed of cast-iron plates to hold water can scarcely be said to have its origin in gas-works, as the iron troughs or water-ways constructed as aqueducts for carrying the water of canals over roads and valleys probably afforded the first examples of the use of iron for such a purpose. Cast-iron aqueducts were common on the canals executed by the late Mr. Telford and Mr. Rennie some time before iron tanks were used in gas-works.* When the tanks are constructed of

* The cast-iron aqueduct which carries the Shrewsbury Canal across the valley of the Tern, at Long Mill, is 186 feet in length. The Pont-y-Cysylte' aqueduct on the Ellesmere and Chester Canal is a far more stupendous concern, the cast-iron trough which carries the canal being 988 feet long by 20 feet wide and 6 feet deep. Both these works were executed by Mr. Telford in the beginning of the present century.

brick-work, they are usually sunk a considerable depth in the ground, so that the top of the tank is either level with the surface, or not more than 3 feet above it. The excavation must be made wide enough to allow a space all round the lifting part of the gas-holder, for the thickness of brick-work, and for a puddle at the back of the wall. In some cases the whole of the ground within the tank is excavated, and then the whole of the bottom must be puddled, the thickness required for this being of course included in the depth of excavation. Suppose a tank be required to receive a gas-holder 100 feet in diameter, and 25 feet deep below the surface; the dimensions of the excavation would be calculated as follows:

	feet.	in.
Gas-holder	100	0
Space for water all round	1	6
Double thickness of brick-work at bottom .	5	3
Puddle, double thickness	6	9
	113	6

so that the diameter of the excavation, exclusive of any slope for the earth, should not be less than 113½ feet. In fact, such an excavation would, in practice, not be made less than 120 feet diameter at the top, and sloped down to 113½ feet at the bottom. The thickness of brick-work I have estimated at 3½ bricks for the bottom, exclusive of footings. This thickness may be gradually diminished by offsets at the back, till at the surface of the ground the thickness is two bricks or 18 inches. This is considerably more than the thickness given by Mr. Clegg, who shows a tank 87 feet in diameter with a thickness of only 18 inches at base and 14 inches at top. Mr. Peckston gives 2½ bricks at base for a much smaller tank, and 14 inches at top. Comparing these tanks with the chamber walls of canal locks, which are seldom so deep, the dimensions I have given will appear insufficient to most hydraulic engineers; it must be borne in mind, however, that the circular form of the tank enables it to resist pressure better than

a straight or slightly curved wall,—that the brick-work has a strong puddle behind it, and the tank is always full of water, which counteracts the pressure of the earth by which it is surrounded. The nature of the ground will of course materially influence a decision as to the thickness of brick-work required in any particular case, and also whether concrete be necessary in the foundations. The dimensions above given may frequently require to be exceeded, while very few cases will occur in which it would be safe to diminish them. The whole of the brick-work should be carried up either in Roman cement, or in the very best hydraulic mortar, such as that made from the lias limestone of Aberthaw, Southam, &c. The use of cement or hydraulic mortar is not recommended for the purpose of making the tank water-tight, as this is effected by the puddle, but in order to prevent an effectual resistance to the solvent power of the water. Most of the common mortars when in contact with water will dissolve by degrees, become soft, and in time the joints will be emptied, and the destructive power of the water will soon show itself on the brick-work. The duration of a tank will materially depend on the perfection of the brick-work, and the complete resistance of the mortar joints is of the utmost importance. It is usually recommended to put in the puddle behind the wall in a more fluid state than it is generally used for canal embankments, dykes, and other hydraulic works, in order that the more compressible part may enter into the joints of the brick-work and form a more complete union with it. The puddle should be used in thin layers of 9 inches or a foot, well cut up, and worked with water and with the workman's tools, and trodden down in the usual way. The best material for puddle is not pure clay, which is apt to crack, but clay with a portion of sand or silt free from stones or other hard masses, and especially free from vegetable fibre of every kind, which would in time decay and leave hollows. The thickness at base of wall above the footings may be 3 feet, diminishing to 9 inches at top. In carrying up the brick-work of the tank, the space

between the puddle and the solid ground will become greater, and this must be carefully filled up with dry and solid material well rammed in thin courses, corresponding with the progress of the wall.

Sometimes the whole of the space inside the tank is not excavated, but a solid core is left in the middle. The whole exterior of this core must be dressed to a proper slope, to prevent the earth slipping and choking up the water-space. As this slope frequently however requires puddling, and the area is greater than that of the bottom of the tank, the saving as compared with the expense of excavating the whole must be very trifling. The annexed specification for the tanks erected by Mr. Croll at Bow Common describes a core to be kept in the middle, the core to have a footing wall at the base, and to be connected with the wall of the tank by an inverted arch.

In order to guide the gas-holder in rising, vertical bars of iron are fixed all round the inside of the tank at intervals of about 9 feet apart. These bars are secured to stones built in with the brick-work, and project 3 inches from the face of the brick-work. The construction of the piers to receive the guide-rods will be understood from the specification.

Attached to the tank is usually a well containing the inlet and exit pipes. The well is generally the same depth as the tank, and about 7 feet in diameter, lined with brick-work and puddled. The inlet-pipe enters at the top of the well and passes down to the bottom of the tank, where a vessel is fixed to receive any tar and moisture still contained in the gas. The inlet-pipe then passes horizontally through the brick-work of the tank and rises up vertically through the water till its open end is about 2 inches above the surface. The outlet-pipe is placed by the side of the inlet at the same height, and after descending through the water passes out through the wall of the tank and enters the stand-pipe well, where another receiver for tar and water is fixed. The outlet-pipe

then passes up the well, and conveys the gas either to a governor or to the main for distribution.

In Mr. Croll's works a single stand-pipe well is constructed for the joint use of all the four tanks, so that it is made of larger dimensions than usual, as will be seen from the specification.

In addition to the parts of the tank which have been already described, it is necessary to have supports on which the roof of the gas-holder rests when sunk in the tank. In Mr. Croll's large tanks these supports are thirty-six in number, consisting of hollow pillars, as specified.

Specification of Work for the Construction of a Brick Tank at Bow Common.

The tank, when finished, to be a true cylinder, measuring 105 feet 9 inches in diameter, and 26 feet 6 inches deep inside, as follows:

The contractor to excavate all earth-work to a depth of 25 feet from the surface line, which includes the depth of the brick-work, puddle, concrete, and the like, minus 5 feet, which the top of the tank may be above the ground line when finished. Should the tank require to be sunk level with the ground, 5 feet of excavation must be added. The substratum of the entire tank to be of puddled clay, properly tempered, to a depth of 3 feet. The brick-work to be commenced on top of the puddle, the walls to be three and a half bricks thick for 6 feet high, exclusive of three double courses of footings, together 9 inches broad on the back of the wall.

An inverted arch to be constructed in the front portion of the wall at bottom, 14 inches deep.

The whole of the footings, the inverted arch, and the wall to the height of the top of the arch, to be built in Roman cement, and good clean, hard, sharp sand, in the proportion of one-half of each. The last two courses of this thickness of wall to be likewise in cement as already described; two bull's eyes, 16 inches diameter, to be formed in the thickness of the walls, as the engineer shall appoint.

The next 6 feet in height of walls to be three bricks thick; the first three courses at the bottom, and which join those of the top of the last height, to be built in cement as already described; the last two courses at the top of this height to be likewise built in cement.

The next 7 feet in height of the walls to be two and a half bricks thick: the first two courses, which join on to the top of the last height, to be built in cement as before described; the last two courses at the top of this height to be likewise built in cement.

The remainder of the walls which thus terminate the sides of the tank to be two bricks thick; the first two courses and last three courses of this height to be built in cement as before described.

A coping of York stone, 3 inches thick by 14 inches broad, to cover the walls at top, closely jointed and bedded in cement. One hundred and ninety-eight blocks of stone, each $10 \times 9 \times 12$ inches, to be built in the sides of the tank, for the purpose of fastening the vertical flat bars to, which guide the gas-holder while rising. Thirty-six bars of iron, each 27 feet long, 6 inches broad, and $\frac{5}{8}$ths thick, to be fastened vertically to the stone blocks above mentioned, and to the coping and brick-work beneath by countersunk-headed bolts, so that the face of the bar will stand 3 inches forward of the brick-work.

Twelve brick piers, each 5 feet by 4 feet 8 inches at the base, solid, diminishing in three set-offs at equal distances from bottom and top, to 4 feet by 3 feet at the top; these pillars to be bound in and built with the side walls of the tank, and built in cement, at the same levels as that of the cement-work in the side walls.

At 8 feet from the top a cast-iron plate to be built into each pier, for the purpose of receiving tie-bolts; this plate to be furnished to the contractor.

Each pier to be capped with a solid block of granite, 2 feet deep by 5 feet 6 inches by 3 feet, with eight $1\frac{1}{2}$-inch holes bored

through its depth, as the Company's Engineer shall appoint. The whole of the brick-work of the sides to be puddled behind with well-tempered clay firmly put in, commencing at 3 feet thick at the bottom, and gradually diminishing to 9 inches thick at the top.

The earth or soil to be firmly pounded in behind this; and all shrinkage to be made good for a period of twelve months from the date of completion.

The bottom or cone inside to be puddled similar to the vertical sides of the tank, and of similar thickness; on top of which will be built a solid layer of concrete, 2 feet thick at the base where it joins the inverted arch, and 1 foot thick at and all over the top. This concrete to be made of good large gravel, cleaned from all earthy matter, and mixed with hydraulic mortar in the usual proportions. A concrete pillar to be brought up, one below each pillar, capped with a stone 18 inches square.

In case of concrete not being found convenient, this cone shall be covered with brick-work 13½ inches thick for one-third of the height, and finished with 9-inch brick-work on the remaining two-thirds. The Company's Engineer shall decide which of the two ways will be adopted, and allowance made in the contract accordingly.

Eighteen hollow pillars, each 19 feet long, 4 inches in diameter, and ½ inch thick, having a flange joint in the middle made fast by bolts; and eighteen hollow pillars, each 6 feet long, 3 inches in diameter, and ⅜ths thick; these to be all connected by ⅝th round rod made fast to each other and to stone blocks bedded in concrete. Each pillar to be fitted with a cross of 2½-inch tie-iron 6 feet long, and supported by struts of 1½-inch angle-iron, bolted to the tie-iron and pillar by ½-inch bolts.

The pillars to have ears cast upon them to receive those struts and the binding rods.

The whole of the brick-work to be built so that the highest part of it will never be more than two feet higher than the

lowest part; the bricks to be the best hard-burnt stocks of the usual size, laid solidly in hydraulic mortar, all solidly flushed at both end and side joints, but not grouted.

The contractor shall furnish all materials of every description, scaffolding, embankment supports, tools, &c., and sink all necessary wells, and keeping the materials, &c., dry until the work is finished and tested. The excavated earth shall not be the property of the contractor further than he requires for the erection of the tanks and other works; but all clay, gravel, sand, or other matter which he may not require in the construction of the tanks, to be at the disposal of the Company for their own uses, but should they not accept of the same, the contractor shall in that case cart it away.

The following is Mr. Croll's estimate of cost for the above tank, with a slight variation however in the stand-pipe tank, which is here estimated as one of 7 feet diameter appropriated to this tank alone, whereas the specification describes a stand-pipe well 10 feet diameter for the joint use of four tanks. This variation, however, will not affect the estimate to any great extent.

Estimate of the Quantities of Brick and Stone Work for Tank of Gas-holder.

Circular brick wall 26 feet high, as follows:

	ft. × ft. in.	Mean Diam. ft. in.	Contents. rods ft.	rods ft.
Bottom portion	4 × 2 6½	106 0½	11 118	
Second „	5 × 2 2	105 8	12 56	
Third „	5 × 1 9½	105 3½	10 36	
Fourth „	6 × 1 5½	104 11½	9 190	
Fifth „	6 × 1 1	104 1	7 58	
				50 186
Twelve piers below the guide-rods, averaging 3 ft. 6 in. by 3 ft., and 24 ft. high			9 240	
Stand-pipe tank, 7 ft. diameter, 9 in. thick, 30 ft. high			1 168	
Internal cone, 25 ft. high, top and bottom diameters 46 ft. and 93 ft.; 9 in. thick			18 96	
Pillars to support roof			4 24	
				33 256
				84 170

		ft.	in.	in.	Diam. ft.	Diam. in.	yds. ft.	yds. ft.
Puddle of the tank . .		28	6 ×	18	107	8	535 11	
,, ,,	cone . .	34	3 ×	12	69	6	277 10	
,, ,,	bottom .	7	0 ×	18	113	0	164 24	
,, ,,	stand-pipe tank .	30	0 ×	18	7	0	36 18	
								1014 9

	ft.
Foundation-stones of tank, 3 ft. by 6 in., mean diameter 104 ft. 6 in.	636
Twelve stone blocks for guide-rods to rest on, 3 ft. by 5 ft., and 2 ft. thick	360
Twenty-four stone blocks for gas-holder to rest on when down, 2 ft. 6 in. by 1 ft. 6 in. thick	30

Estimated Cost of Brick and Stone Work in Tank for Gas-holder.

	£.	s.	d.
50 rods 186 ft. in circular brick wall, at £15 per rod . .	760	5	2
33 rods 256 ft. in piers, stand-pipe tank, internal cone, and pillars, at £15 per rod	509	2	4
1014⅓ solid yards of puddle, at 4*s*. per yard	202	17	4
636 super feet of foundation stones in tank, at 9*d*. per foot .	23	17	0
360 solid feet of stone blocks for guide-rods, at 2*s*. per foot .	36	0	0
30 super feet of stone blocks for gas-holder, at 9*d*. per foot .	1	2	6
6547 solid yards of excavation, at 2*s*. 6*d*. per yard . . .	818	7	6
	£2351	11	10

N.B.—To increase the size of this tank to hold a gas-holder that contains 412,000 cubic feet, will raise the cost to £2367. 8*s*. 4*d*.

In some districts where stone is abundant it may sometimes be cheaper to build the tank of masonry, and if the material be properly dressed with squared beds and joints, the same thicknesses as those prescribed for brick-work carried up with puddle in the same way, will fully answer the purpose. If an inferior kind of building be adopted, like that called rubble masonry in Scotland, a somewhat greater thickness will be necessary. After all that can be said about strength and

quality of materials for building, so much will depend on the particular circumstances of each case, that no general rules can be given. Practical experience in the nature of different strata, their solidity, their permeability by water, and other properties, will often dictate a mode of proceeding at variance with all the rules of theory. There is nothing peculiar, however, in the construction of either brick or stone tanks for the purposes of gas-works,—no difficulties which do not occur again and again to the civil engineer engaged in the active practice of his profession.

The lifting part of the gas-holder was formerly made of much heavier plate and far more abundantly strengthened by angle-iron and stays than at present. The first gas-holders were in fact almost strong enough to contain steam, while, in modern times, a more intimate acquaintance with gas has taught us that a fluid which may be imprisoned in a vessel no stronger than a silk balloon does not require the same precautions as steam. The great weight of the first gas-holders introduced the necessity of a complicated system of equilibration chains and counterbalancing weights in order to relieve the gas from the great pressure of the holder, whereas in modern practice the gas-holder is commonly too light to afford the requisite pressure, and requires to be itself weighted.

As there are many country works without the advantage of a governor, and as the gas-holder should then be capable to the utmost possible extent of regulating the pressure of the gas, I propose to describe, first of all, the mode of adjusting the pressure of the gas-holder so as to make it equal and uniform for all heights; and, secondly, to enter on the mode of producing any required or given pressure either greater or less than that afforded by the gas-holder itself.

ON REGULATING THE PRESSURE ACCORDING TO THE RISE AND FALL OF THE GAS-HOLDER.

In some works the gas-holder is balanced by a chain

passing over pulleys and hanging down to the ground without any suspended weight, as in fig. 58. This chain is called the chain of equilibration, and must be of such a weight as to balance the gas-holder in every position, from extreme immersion to the point where it is nearly out of the water. Now the weight to be given to each unit (say a foot of the chain's length) bears a constant relation to the weight of water displaced by the same unit or length of the gas-holder. Let us assume the weight of 1 foot in depth of the gas-holder to be w, and put the specific gravity of the iron $= g$, then we have by the laws of hydrostatics w : the weight of water displaced by 1 foot of the gas-holder : : g : 1000 the specific gravity of water; or *the weight of water displaced* $= \frac{1000\, w}{g}$. Now as the gas-holder in rising 1 foot gives over a foot of chain to the other side of the pulleys and at the same time parts with a foot on its own side, it follows that a chain which weighs per foot one-half of the above quantity, or $\frac{1000 w}{2 g}$, will fulfil the required condition of balancing the gas-holder. To apply this in practice, let us assume a gas-holder 100 feet diameter, constructed of No. 11 plate iron, the weight of which per square foot is 5 lbs.

	lbs.
Hence we have $100 \times 3{\cdot}1416 \times 5$ lbs. = ...	1571
To which add $\frac{1}{6}$th for rivets, overlap of plates, &c. .	262
Weight of 1 foot in depth of gas-holder . . .	1833

Calling the specific gravity of wrought-iron plate 7700, we have $\frac{1833}{7{\cdot}7} = 238$ lbs. for the weight of water displaced by 1 foot, and consequently half this amount or 119 lbs. for the weight of each foot of chain.

In most of the old gas-holders where equilibrating chains are used, the vessel is suspended from three points at equal distances round the circumference. The upright standards support three cast-iron frames, arranged in plan, in the form of an equilateral triangle. Two of these frames carry pulleys, over

which pass the chains from the point of suspension. The third pulley is placed at the intersection of two of the frames. The other two chains converge towards this third pulley, and pass over the edge of the gas-holder by separate pulleys. The balance is here effected by three separate chains, each of which must of course weigh one-third of the whole weight, as determined above.

To find the pressure on the gas due to the weight of the gas-holder.—In this case, the whole weight of the gas-holder is taken into consideration, so that the pressure is determined for the vessel when lifted up to its extreme height out of the water. Then, for any other height the equilibrating chain comes into play, and causes the pressure to be the same, however much or however little the gas-holder may be immersed.

Let W be the weight in pounds of the entire gas-holder, and A the area of the top in square feet, then the pressure in pounds per square foot will be $\frac{W}{A}$. The pressure is usually required in inches of water, which may be taken as weighing $62\frac{1}{2}$ lbs. per cubic foot. Hence $\frac{W}{62\frac{1}{2} A}$ = pressure expressed by the depth of a column of water in feet, or $\frac{W}{5{\cdot}21 A}$ = pressure in inches of water. For example, take a gas-holder 100 feet diameter and 39 feet high, the weight of which as given in detail by Mr. Clegg would be 100 tons. Here $W = 100 \times 2240 = 224{,}000$ lbs., and A the area $= 7854$ square feet. Hence $\frac{224000}{5{\cdot}21 \times 7854} = 5{\cdot}47$ the pressure in inches. The working pressure of this gasometer is therefore said to be equal to a column of water 5·47 inches in height. As this pressure would be considerably too much, such a gas-holder would require to be furnished with a counterbalance, which brings us to the consideration of the next problem.

The weight and area of a gas-holder being given, to determine the counterbalance weight required to make it work at any less pressure, say at n inches. Here it is evident, using

the same letters as before, $W - 5{\cdot}21\ A\ n =$ weight of counterbalance required. Suppose it be required to find the counterbalance necessary to make the last gas-holder work at a pressure of 2 inches; then $224{,}000 - 7854 \times 5{\cdot}21 \times 2 = 224{,}000 - 81{,}838 = 142{,}162$ lbs. the weight of counterbalance.

The weight of this gas-holder is so great, that in order to reduce the pressure to anything like a proper amount for regulating the flow into the mains, an enormously heavy counterbalance would be required. Where no governor is used, the working pressure of gas-holders seldom exceeds that of a column of water $1\frac{1}{2}$ inch deep; but where the gas passes through a governor, the gas-holder may very advantageously have a pressure of 3 inches. Where again the gas is required to pass from one gas-holder into others, the pressure in the first is often considerably more than this, as it facilitates the flow of the gas, while the gas-holder which is actually used to regulate the pressure in the mains is of course adjusted so as to have a pressure suitable for the purpose.

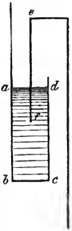
I have already alluded to the great changes which have been gradually taking place in the construction of gas-holders, which are now made so light as more commonly to require loading themselves than to need the aid of counterbalances. In the department of gas-engineering there are several manufacturing firms of great eminence who devote themselves wholly and chiefly to the manufacture of gas-holders, and the concentrated attention which the subject thus receives has undoubtedly led to very favourable results. An engineer in erecting gas-works may receive tenders for his gas-holders from a number of well-qualified contractors who have each their own method of construction, and may, if he chooses, be saved much of the trouble and responsibility of designing these vessels for himself.

The modern method of erecting gas-holders, as practised in those at Bow Common, is to have no suspension whatever, but a series of guide-rods equal to the whole height which the holder is to rise. These guide-rods are placed round the cir-

cumference of the tank, at the rate of about 1 to every 8 or 9 feet of diameter, so that they stand from 25 to 30 feet apart, and they are connected at top by tie-rods or light castings, which serve to preserve them in a vertical position. The talented American engineer who visited this country to obtain information on the subject of gas-works for the Town Council of Philadelphia preferred the system of triangular suspension, however, as described in the preceding pages. He proposed two gas-holders capable of containing the maximum quantity of gas required for consumption in twenty-four hours; each gas-holder to be 50 feet diameter and 18 feet deep, with single lifts, and working with a pressure equal to 3 inches of water. Each gas-holder to be suspended from three points, with chains leading to and terminating at one point, being the apex of a triangular frame of wood-work. To these chains thus connected the counterbalance was hung. Mr. Merrick, the Engineer, observes, in his Report, that the plan of triangular suspension has one decided advantage in a climate liable to falling or drifting snow: the weight of snow falling on one side of the vessel will not affect its perpendicular position, while with the guide-rods it might affect the free play of the gas-holder.

TELESCOPIC GAS-HOLDERS.

Fig. 59.



These vessels, which afford the means of storing nearly double the quantity of gas on the same space of ground, are very valuable where economy of space is an object, as in most large towns. The telescopic gas-holder consists of an upper and lower cylinder, the latter working in the tank of water, as already described, and the upper one, of somewhat smaller diameter, being connected with the lower one by means of a very ingenious hydraulic joint. Thus the whole side of the upper vessel is turned up all round so as to form a well, *a b c d*, in fig. 59, from 14 to

20 inches deep, and from 6 to 9 inches wide. The side of the lower vessel is also turned down in a corresponding manner, so that the part *e f* enters the well or water lute surrounding the upper holder. This water lute being always kept filled with water, acts as a perfect seal to prevent the escape of gas while the lower holder is rising or is at all out of the tank. The two parts of which this holder consists are both contained in the tank when entirely empty of gas. As the latter enters, the upper holder rises, the water in the tank serving to confine the gas and prevent any escape. When the upper holder is leaving the water of the tank, the point *d* comes opposite to *f*, when the part *ef* enters the well, and seals hermetically the two holders together. They then begin to rise together, the seal between the two, and the water of the tank, both serving to prevent escape of gas during the remainder of the rising process. It is frequently necessary in telescopic gas-holders to suspend both the upper and lower vessel. In this case, triangular suspension may be adopted for the upper, with a frame of cast iron or wood connecting the uprights at top, and carrying the pulleys and converging chains as already described. At the same time, the lower vessel must be balanced by means of chains and separate weights suspended from each of the guide-rods, as its position of course prevents the use of such a frame as that used for suspending the upper vessel. In order to insure the proper working of the two vessels together, it is usual to fix on the upper edge of the lower cylinder a series of friction-rollers, the periphery of which presses on the inner vessel, serving to make the motion uniform and to preserve the shape of both cylinders. These friction-rollers are usually from 4 to 6 inches in diameter, about 4 inches broad, and placed 8 or 9 feet apart all round the circumference of the lower vessel. The tank is usually kept full of water, to within an inch of the top. The inlet and exit pipes both enter at the bottom of the tank and pass up through the water, their open ends standing about an inch above the surface. These pipes in

large works are commonly 10 or 12 inches in diameter, and both dip into a stand-pipe well just outside the tank, in order to deposit any tar and water which they contain. The bottom of this well is made somewhat lower than the bottom of the tank, and is furnished with pumps for emptying the tar. Mr. Clegg recommends the adoption of a wooden curb to be fixed around the lower edge inside the lower cylinder of the gas-holder. The use of this curb, which is usually made of Memel logs, with a scantling of 12 inches $\times$ 12 inches, scarfed and fastened together by trenails, is to regulate the flow of gas from one gas-holder to another. He also recommends that the pressure of all the gas-holders at the same works should be regulated and equalized by adding to or reducing their curbs, so that the pressure will not vary more than $\frac{3}{10}$ths of an inch. When the gas-holders are so adjusted, the extra pressure of any one holder, whose curb is nearly out of the water, will cause the gas to flow off into another gas-holder which is nearly empty, and with its curb consequently immersed in the water.

The thickness of plate commonly used in the construction of gas-holders varies from No. 18 to No. 11 wire-gauge; the first of these being less than $\frac{1}{20}$th of an inch in thickness, and weighing 1·86 ℔. per square foot, while the latter is $\frac{1}{8}$th of an inch thick and weighs 5 ℔s. per square foot.

Where very thin plates are used, a greater proportion of stays and bolts are necessary, whereas in very large gas-holders, where No. 11 plate is used, the proportion is much less, the principal weight being in the plates and in the angle-iron curbs to which they are riveted.

Mr. Clegg gives an example of a gas-holder 36 feet in diameter and 12 feet deep, made of No. 18 wire-gauge for the sides, and No. 17 for the top; total weight of gas-holder 6 tons 5 cwt. 2 qrs. 21 ℔s.; tripods and guide-rods, 5 tons 2 cwt. 1 qr. 21 ℔s. Total cost of gas-holder, including erection, £247. 10*s*. Brick tank for the above, £188. 6*s*. 6*d*.

Another example, also by Mr. Clegg, is a gas-holder 50 feet

diameter and 18 feet deep, containing 35,300 feet. Top, No. 14 wire-gauge; sides, No. 15 ditto; total weight of gas-holder 12 tons 18 cwt. 2 qrs. 27 lbs.; tripods and guide-rods, 11 tons 6 cwt. 3 qrs. 1 lb. Cost, including erection, taking the cast-iron work at £7. 10s. per ton, £541. 2s. Brick tank for the above, £316. 8s.

Another example is, 87½ feet diameter and 25 feet high. Sides of No. 16 wire-gauge, and top of No. 14; total weight of gas-holder 38 tons 10 cwt. 1 qr. 6 lbs.; tripods, bolts, brackets, &c. 41 tons 7 cwt. 3 qrs. 8 lbs. Estimate for gas-holder, including erection, £1609. 10s. Brick tank for the above, at £16 per rod, £749. 12s. 6d.

Another example mentioned by Mr. Clegg is the large gas-holder at the Pancras Station of the Imperial Company, 100 feet diameter and 39 feet high, containing 300,000 cubic feet. The thickness of the plate used for the sides of this is No. 12 and No. 13, and No. 12 for the top; total weight of gas-holder 100 tons 6 cwt. 3 qrs. 17 lbs.; brackets, guide-rods, tripods, &c. 116 tons 14 cwt. 1 qr. 8 lbs. The cost of this is not given.

A very excellent specification for a telescopic gas-holder, 100 feet in diameter and 45 feet high, is given in the 'Gas Journal' of August, 1849. The roof and top tier of side plates in this gas-holder were to be No. 11 wire-gauge, and all the other side plates of No. 12.

Mr. Croll's large gas-holders, of about the same size, at Bow Common, have the top and bottom tier of plates in the sides of No. 11 wire-guage, and the roof and all the other plates of No. 12.

The following copies of specifications for gas-holders and the stand-pipe well or hydraulic room attached to the tank will supply many details which have not been alluded to for want of space, and will furnish examples of the best kind of construction in use at the present day. For the first specification I am indebted to the 'Gas Journal' for August, 1849, p. 49.

"*Specification of an Iron Tank and Gas-holder.*

"*Cast-iron Tank.*—One cast-iron tank of 101 feet diameter, and $22\frac{1}{2}$ feet depth, both inside measure and exclusive of the flanges. The flanges to the bottom to be on the inside, the others on the outside, and the whole of them to project $3\frac{1}{4}$ inches at the least. The bottom is to be 1 inch thick throughout, excepting the outside row of plates and the row next to it; the outside row to be $1\frac{1}{4}$ inch thick, and the next row to diminish in thickness from $1\frac{1}{4}$ to 1 inch. The centre plate is to be $1\frac{1}{2}$ inch thick. The first tier of side plates is to be $1\frac{1}{4}$ inch, the second $1\frac{1}{4}$, the third $1\frac{1}{8}$ inch, the fourth 1 inch, and the fifth or top tier 1 inch thick. Each of the side plates is to be of such a width as to allow of 75 in the circumference; each plate to be 4 feet $6\frac{1}{2}$ inches deep; and each tier of plates is to be numbered in the casting of them, such numbers to be 1, 2, 3, 4, 5, beginning at the bottom tier.

"The tank is to be bound together by five wrought-iron hoops, which are to be fixed as shown in the drawings, each hoop to be 5 inches wide and $1\frac{1}{4}$ inch thick.

"The tank is to be bolted together with full 1-inch bolts of wrought iron, not more than 7 inches asunder from centre to centre of each bolt, and properly cemented together with iron cement. A flange column is to be fixed on the centre plate of the tank so as to support the roof of the gas-holder when down, and to be of the height and dimensions shown in the drawings. The plates of the tank, exclusive of the bolts, cement, hoops, and centre column, to weigh   tons; and all to be delivered, and the tank to be erected agreeably to drawings, and to the satisfaction of the committee of management of the company or their engineer, for a sum to be fixed, free of any other charge whatsoever, unless the aggregate weight of the plates shall exceed or be less than six tons of the estimate above stated, in which case the price to be charged or deducted is to be after the rate of £   per ton. The company is, however, to pay for nothing beyond the said excess of six tons,

and should the deficiency be more than the six tons, then the company is to be allowed from the price to be paid for the tank after the rate of £20 per ton, for such deficiency, whatever it may be.

"Each of the plates and castings is to be numbered and marked on the inside with its own weight with white-lead paint. The company is to provide good and proper brick or stone foundations, and keep out water; but the contractor is to find and use the necessary materials for scaffolding, and also all pulley blocks and falls, and every other material that may be required in erecting and completing the tank.

"The whole of the plates and materials for the tank are to be delivered, and the tank is to be erected complete, on or before the end of thirteen weeks after notice shall have been sent in writing to the contractor from the company, either by hand or by post, that the foundations for the tank are sufficiently prepared for him to begin his work.

"Should the tank not be completed as above stated, then the contractor is to be subject to a fine to be reserved from his account of £50 per week from the date at which it is agreed that the tank shall be completed; and should the delay exceed four weeks of the time stipulated, then the company is to be at liberty to employ any other party to complete the tank without being liable to the contractor for payment, either for the plates delivered or such part of the works as he may already have executed.

"*Hydraulic-room, two* 18-*inch Valves, and six* 18-*inch Quarter Bends.*—One circular hydraulic room with a bottom and top, to be 12 feet diameter and 18 feet deep inside measure, and $\frac{7}{8}$ths of an inch thick throughout, with the requisite flanges. The flanges to the bottom are to be on the inside, and all the others on the outside. The whole to be fixed together with $\frac{3}{4}$-inch bolts fixed in the same manner as in the tank, and completed according to the plan and dimensions described in the drawings.

"Two 18-inch pneumatic lifting-valves, and six 18-inch

quarter bends, to be cast agreeably to drawings, and the said valves are to be fitted ready for use. The contractor, on failing to deliver and complete the said hydraulic-room, valves, and bends, to the satisfaction of the committee of management or their engineer, on or before the expiration of the above notice referring to the tank, is to be subject to a penalty, to be subtracted from his account, of £100; and should the delay exceed four weeks of the time stipulated, then the company is to be at liberty to employ any other party to complete the said hydraulic-room, valves, and bends, without being liable to the contractor, either for the castings delivered, or for such part of the said hydraulic-room, valves, and bends as he may have already executed.

"*Gas-holder.*—One circular gas-holder to be made of the best plate and English iron, upon the telescope principle, to the above-mentioned tank. It is to be in two parts, and correspond in diameter and height with the dimensions given in the drawings. The roof and top tier of side plates of the gas-holder are to be of No. 11 wire-gauge, and all the other side plates are to be of No. 12 wire-gauge. Each part is to be 22 feet deep, and is to have a hydraulic joint 15 inches deep and 8 inches wide of No. 10 wire-gauge, one part of the joint to be connected with the top of the bottom part. The top edge of the cup and the bottom edge of the dip are to be bound by half-round iron, 2 inches by 1 inch thick. The roof of the gas-holder is to be a dome roof, supported within in the usual way, with sufficient wrought-iron framework, and twenty-four trusses, and the requisite intermediate rafter bars, strutted as shown in the drawings. The side of the upper part is to have twelve vertical truss bars, equidistant from each other in the circumference inside. The lower part is to have twenty vertical plates of flat iron, 3 inches by $\frac{3}{8}$ths of an inch, reaching from the top to the bottom on the inside, with the requisite intermediate bars, strutted as shown in the drawings. The gas-holder is to have twenty-four cast-iron guide-pulleys and carriages, twelve of which are to be attached to the upper part

and twelve to the top of the bottom part, to work upon guide-rods, and also twelve friction rollers are to be attached to the dip of the hydraulic cup on the top of the lower part of the gas-holder, to work between its upper and lower parts; thirty-six friction rollers are also to be attached to the bottom edge of the lower part, to work between it and the tank, all as shown in the drawings. The whole to be of the requisite dimensions to suit their respective places, and the rim of the lower part is to be strengthened with a double wrought-iron curb of angle-iron 4 inches by 1 inch at the root, and a ring of bar-iron 4 inches by 1 inch in thickness. The sheets of the gas-holder are not to exceed 4 feet in length by 2 feet 2 inches in height; and the rivets are not to be less than $\frac{1}{4}$ inch in diameter, nor more than 1 inch asunder from centre to centre, their heads showing on the outside. Twelve eye-bolts and shackles are to be attached to the upper edge of each gas-holder at equal distances from each other.

"The said gas-holder, &c. are to be delivered and executed complete according to drawings, and so as to apply to the said tank, and to the columns and frame after mentioned, and to the satisfaction of the committee of management or their engineer. The contractor is to provide himself with and use the pulley blocks and falls, and every other necessary material for constructing the scaffolding, which he is to erect at his own expense.

"The materials of the gas-holder, including friction rollers, pulleys, &c., &c., and all their appendages, are to be delivered, and the whole erected and fitted complete, on or before the end of thirteen weeks after notice shall have been given as above stated in reference to the tank, that the said tank is sufficiently completed to enable the contractor to commence the building of the said gas-holder, &c., &c., for a sum to be fixed free of any other charge, such sum to include the price of the columns and frame after mentioned.

"Should the said gas-holder, with all its appendages, and also the columns and frame after mentioned, not be completed as

above stated, then the contractor is to be subject to a fine of £50 per week, to be reserved from his account, from the date of the period wherein it may be agreed that they shall be completed; and should the delay exceed four weeks of the time stipulated, then the company is to be at liberty to employ any other party to complete the said works, without being at all liable to the contractor for payment for any part of the works which he may have already executed.

"*Columns and Frame.*—The said gas-holder is to have twelve cast-iron columns, and a cast-iron frame to connect them together at equal distances from each other in the circumference, as shown in the drawings.

"Each column is to be composed of four lengths, and when erected to be, including the said frame, about 62½ feet high, from the top of the foundations to the top of the frame, so that the whole frame shall be arranged to one level. The columns to taper from 24 inches diameter at their bases to 16 inches at their tops, and be 1⅛ inch thick at bottom, tapering to 1 inch at top. The metal of the frame is to be 1 inch thick throughout. Each casting is to be numbered and marked with its weight with white-lead paint.

"Twelve wrought-iron guide-rods of railroad iron, according to drawings, and with the requisite chairs, to be fixed and applied one to each column, and reach from the top of the tank to the under side of the frame; and each column is to have a foundation plate of cast iron 6½ feet long, 4 feet wide, and 2 inches thick, and four wrought-iron holding-down pins of 2 inches square iron, 10 feet long each, and to be fixed with the necessary lead, as shown in the drawings.

"The columns are to be bound together with a cast-iron frame as mentioned, which is to be composed of twenty-four girders, to be connected in the circumference of the tank from column to column at top, and each girder is to be fitted to its respective columns and to its respective girders. The whole to be properly chipped and secured together with proper

screwed bolts, nuts, collars, &c. of wrought iron, cemented together with iron cement. The plan of the frame, and also for the elevation section, bearings, and mode of connecting the columns, guide-rods, and girders, to be according to drawings.

"The said columns and frame, with their appendages, are to be delivered and erected complete, so as to apply to the said gas-holder and tank, and to the satisfaction of the committee of management or their engineer, and within the time and under the conditions named in respect to the gas-holder."

SPECIFICATION OF GAS-HOLDER AT CENTRAL GAS CONSUMERS' WORKS AT BOW COMMON.

Four Telescopic Gas-holders.

Gas-holder in two lifts, rising together 50 feet, independent of 6 inches of seal when gas-holder is up. The exterior 'lift' to be 103 feet $7\frac{1}{2}$ inches diameter, and 25 feet 6 inches deep on the vertical sides.

The water lute to measure 20 inches deep by 9 inches wide, constructed of a 5-inch angle-iron on the outside, and a $3\frac{1}{2}$-inch angle-iron on the inside; the former $\frac{5}{8}$ and the latter $\frac{1}{2}$ an inch thick, joined together on the top and on the vertical inside with boiler plate $\frac{1}{4}$ inch in thickness; the joinings each to be lapped with a piece of 7 inches long by the breadth of the joint, and $\frac{1}{4}$ inch thick, riveted with $\frac{1}{2}$-inch rivets, countersunk on the inside of the cup $1\frac{1}{4}$ inch apart, centre to centre. The vertical inside of the cup to be stiffened round the bottom with $1\frac{1}{2}$-inch half-round iron fastened to the side by $\frac{3}{8}$ rivets 12 inches apart.

Plates.—The highest and lowest tier of plates on the vertical sides to be $\frac{1}{8}$ of an inch in thickness. The lap of these plates to be $1\frac{1}{2}$ inch, fastened to their respective angle-irons by $\frac{3}{8}$-inch rivets, $1\frac{1}{4}$ inch apart, centre to centre.

The lowest tier of plates to have a 5-inch angle-iron fastened horizontally round the bottom on the inside, to form a bottom curb, with $\frac{1}{2}$-inch rivets, $1\frac{1}{4}$ inch from centre to centre.

Twenty-four corrugated stiffening bars (the folds forming corrugation to be 1 inch in depth), 6 inches broad by $\frac{3}{8}$ inch thick, standing the whole height of the sides, and bolted to the top and bottom angle-irons by two $\frac{5}{8}$-inch bolts at each end, and likewise to the plates on the vertical sides, every foot in height, by $\frac{3}{8}$-inch bolts. These bars will stand vertically on the inside.

All the tiers of plates which fill in between the top and bottom tiers, and which will form the covering for the vertical sides, to be of No. 12 Birmingham gauge, having $1\frac{1}{4}$-inch lap, and fastened with $\frac{5}{16}$-inch rivets 1 inch apart, centre to centre.

Thirty-six cast-iron rollers, 6 inches in diameter and 6 inches long, working into proper wrought-iron sheaves, to be bolted to the bottom 5-inch angle-iron with four $\frac{5}{8}$-inch bolts each.

Twelve slide carriages and rollers complete, to be bolted on to the top of the water lute; the rollers to be not less than 12 inches over the flanges, and to receive a guide-rod 3 inches broad.

Thirty-six rollers, 4 inches diameter and 6 inches long, working into proper wrought-iron sheaves, to be bolted to the inner angle-iron of the water lute, for the purpose of guiding the upper lift.

The upper lift of gas-holder to be 101 feet $4\frac{1}{2}$ inches in diameter and 26 feet deep on the vertical sides. The upper ring or curb, to which the top and sides are to be fastened, to be constructed of a 5-inch angle-iron $\frac{5}{8}$ths of an inch thick, which will stand on the outside; on top of this will be riveted a ring of boiler plate $\frac{1}{2}$ inch thick and 12 inches broad, in segments not more than 6 feet long, lapped at the joinings with pieces 7 inches long by the breadth of the joint. A ring of 4-inch angle-iron to be riveted along the inner edge of the annular ring of boiler plate on the inside. The rivets to be used in the formation of this curb to be $\frac{5}{8}$ths of an inch diameter and $1\frac{1}{4}$ inch from centre to centre. The outer circle of

the plates on the top, the first on the vertical sides at top, and the last on vertical sides at bottom, to be $\frac{1}{8}$th of an inch in thickness, with a lap of $1\frac{1}{2}$ inch, riveted with $\frac{3}{8}$ rivets $1\frac{1}{2}$ inch apart, centre to centre.

The remainder of the crown plates to be of No. 12 Birmingham wire-gauge, all riveted with $\frac{5}{16}$ rivets, the lappings at the joints to be $1\frac{1}{4}$-inch rivets, 1 inch from centre to centre; the whole top to be constructed flat (not raised).

The remainder of the side plates which will fill in between top and bottom plates, and which will thus complete the sides, to be of No. 12 Birmingham wire-gauge, all riveted with $\frac{5}{16}$ rivets, 1 inch from centre to centre, with $1\frac{1}{4}$-inch lap.

The lower row of plates on the sides to be fitted with a water lute of 20 inches deep and 9 inches wide, formed of a 4-inch angle-iron on the inside, and a $3\frac{1}{2}$-inch angle-iron on the outside, and joined by boiler plates $\frac{1}{4}$ inch thick. The outer vertical side of water lute to be likewise boiler plate $\frac{1}{4}$ inch thick, riveted to the $3\frac{1}{2}$-inch angle-iron, and bound all round the top with $1\frac{1}{2}$-inch half-round iron, riveted on with $\frac{3}{8}$th rivets 12 inches apart.

The joints in the water lute to be lapped with pieces 7 inches long by the breadth of the joint, and $\frac{1}{4}$ inch thick. The rivets to be used in the formation of the water lute to be $\frac{1}{2}$ inch, countersunk on the inside of the cup, $1\frac{1}{4}$ inch apart, centre to centre.

Twenty-four trussed rods standing on the inside, vertically bolted to the curb at the top and the 4-inch angle-iron at the bottom with two $\frac{3}{4}$ bolts, constructed of 4-inch flat-bar $\frac{1}{2}$ inch thick, and stiffened behind with a $\frac{3}{4}$ round rod, having a double-acting screwed collar in the middle.

These trusses to be placed at equal distances round the sides, one opposite to each guide-rod. The outer and inner angle-iron of the top curb to be connected by 2-inch angle-iron and bolted at the angles by $\frac{5}{8}$th bolts.

Twelve slide carriages and rollers complete (each with a frame which will stand against the inside of the crown), to be

bolted on the top; the rollers to be not less than 18 inches over the flanges, and to receive a guide-rod 3 inches broad.

The whole of the riveting to be made with rove-headed rivets, excepting in the water lutes, where the rivet-heads will be countersunk; the plates to be all hammered or otherwise made flat, for the lappings of the plates to have a cord inserted well saturated with red-read. The whole of the outside to have three coats of red-lead and litharge paint.

The gas-holder to be made perfectly gas-tight and geometrically correct. The whole of the sheet iron to be of the best quality, perfectly sound, and free from blisters or other defects. The plates each to contain not more than 8 square feet. The angle-iron, tee-iron, and boiler plate to be all batted where the ends meet, and all rivets above $\frac{5}{16}$ths to be riveted hot.

The gas-holder, when completed, to weigh not less than 90 tons.

GUIDE-RODS, &c.

The guide-rods to be each 53 feet high, 4 feet broad at 2 feet from the base, swelling out to 5 feet at the base, and tapering to 9 inches broad at the bottom. Twelve rods to each gas-holder.

The bottom to be made fast to a stone block, and the brickwork beneath by eight $1\frac{1}{4}$ bolts, each 8 feet long, having a cast-iron washer plate at the bottom, not less than 5 feet $\times$ 2 feet, and $1\frac{1}{2}$ inch thick.

The guiding-rods to be perforated leaves, cast in three convenient lengths, made fast to each other by eight 1-inch bolts, passing through the flanges, and clean iron cement firmly caulked in the flanges, to be $1\frac{1}{2}$ inch thick, $2\frac{1}{2}$ inches broad, clear of the mid-feather, which will be 1 inch thick.

At four points the guide-rods at the base shall consist of an open casting, stretching between tank and tank, and thus compose the lower portion of two guide-rods; above this casting the remainder of these two guide-rods shall proceed as in all the others, and be bound together at two places by cast-

iron beams of the size shown, bolted to the guide-rods by four $\frac{3}{4}$ bolts at each end; these castings to be of the same thickness as the other guide-rods.

The flanges of the guide-rods to measure 6 inches over and 1 inch thick, supported by fillets of 1 foot 6 inches apart.

The base of the guide-rods to be $1\frac{3}{4}$ inch thick, with five strong fillets extending to the outside of the base and 12 inches up the leaf.

The perforations in the guide-rods to be of such a size that between each opening and between the openings and the outside of the rod there will never be less than an average of 4 inches in breadth of solid iron.

A malleable-iron shoe, with a bolt standing 9 inches high in the centre, to be bolted to the top flange of each guide-rod.

The whole of the guards to be fastened together at the top by a 6-inch tee-iron (wrought) having proper eyes to pass over the bolts in the top of the malleable-iron shoes; these eyes to be separate from the tee-iron, clipping it and made fast to it by cotter pins, so that the length of the binding tee-iron can be altered at pleasure.

A cast-iron leaf to be bolted to the front of each guide-rod, extending up its whole height; this leaf to be 6 inches broad. The flange which bolts to the guide-rods to be 6 inches broad by 1 inch thick, with bolt-holes every 3 feet in height, one on each side of the mid-feather, and bolted to the guide-rod by 1-inch bolts. The front flange to be only 3 inches broad.

A runner of 4-inch tee-iron to be bolted to the bottom flange of the upper portion of the guide-rods, binding the guide-rods one to the other, at such a distance from the front as will not interfere with the action of the gas-holder.

The above guide-rods to be erected perfectly perpendicular in a substantial and workmanlike manner; the whole to receive two coats of red-lead oil paint, and the action of the whole guaranteed for twelve months.

Quantities in a gas-holder.—Upper lift, 101 feet $4\frac{1}{2}$ inches,

and 24 feet deep; lower lift, 103 feet 7½ inches, and 25 feet 6 inches deep, rising 50 feet.

Top Curb.

	tons	cwt.	qrs.	lbs.
Angle-iron, 5-in., contains 262 ft., at 25 lbs.	2	18	2	10
Annular ring (12 in. broad), 318 ft., at 20 lbs.	2	16	3	4
Angle-iron (3 in. underneath), 155 ft., at 15 lbs.	1	0	3	1
Angle-iron trussing to curb	1	3	1	3

Crown.

Outer ring of plates (5 ft. long, ⅛ thick), 1516 sq. ft., at 5 lbs.	3	0	3	2
Remainder of crown, 6575 ft., at 4·38 lbs.	12	1	7	14

Water Lute.

5-in. angle-iron (½ thick), 265 ft., at 20 lbs.	2	7	1	8
3½-in. ditto (½ thick), 200 feet, at 20 lbs.	1	15	3	3
Annular ring of boiler plates (6½ broad), 170 ft., at 10 lbs.	0	15	1	2
Vertical side of lute (10 in. broad), 287 ft. 6 in., at 10 lbs.	1	5	2	19
Binding rim, 323 ft., at 4 lbs.	0	11	2	4

Side Plates.

First and last row (⅛ thick), 1275 ft., at 5 lbs.	2	16	3	18
Remainder of sides ($\frac{1}{10}$ thick), 7562 ft., at 4·38 lbs.	14	15	2	24
Twenty-four trussed rods on inside	2	6	2	19
Upper lift	49	17	3	19

Lower Lift.

Top, 5-in. angle-iron (⅝ thick), 290 ft., at 25 lbs.	3	4	3	11
3½-in. ditto (½ thick), 198 ft., at 20 lbs.	1	15	1	12
Annular ring on water lute (½ thick), 172 ft., at 20 lbs.	0	15	1	12
Vertical side of ditto, 267 ft., at 20 lbs.	2	7	3	2
Binding rim	0	11	1	20
Bottom curb, 5-in. angle-iron (½ thick), 289 ft., at 20 lbs.	2	11	2	12
Carried forward	61	4	1	4

	tons	cwt.	qrs.	lbs.
Brought forward	61	4	1	4
Sides.				
First and last course ($\frac{1}{8}$ thick), 1340 ft., at 5 lbs. .	3	0	0	0
Remainder of sides ($\frac{1}{10}$ thick), 7589 ft., at 4·38 lbs. .	14	16	3	3
24 corrugated bars, 25 ft. 6 in. × 9 in. × $\frac{1}{4}$ in. . .	4	1	1	24
	83	2	2	3
Carriages, in all, 2 tons 10 cwt.; rivets, 2 tons 15 cwt.; bolts, 10 cwt.	5	15	0	0
	88	17	2	3
Added since	1	2	2	0
	90	0	0	3

The weight of this gas-holder, as given above, is considerably more than that stated by Mr. Croll in his evidence of the year before. As that evidence gives the weights of the various parts and also the prices at which they are estimated, they are inserted below, as handed in to the Committee of the House of Commons.

Estimate of Gas-holders.

		tons	cwt.	qrs.	lbs.
Two 4-inch angle-irons, forming water lute of both halves, their united length 628 ft. 9 in., equal to 419 sqnare ft., at 2 lbs. to a foot		3	14	3	11
Two 2-inch angle-irons, forming the remaining part of water lute; total length 634 ft. 10 in., equal to 211 square ft. 7 in., at 10 lbs. to a foot . . .		0	18	3	15
Two 1-inch angle-irons, making a binding selvage at water lute; total length 635 ft. 10 in., equal to 105 square ft. 9 in., at 10 lbs. to a foot		0	9	1	24
A 6-inch T-iron at bottom, 319 feet long, containing 319 square ft., at 20 lbs. to a foot		2	1	2	22
Malleable angle-iron curb, at top 9 in. broad, 320 ft. 6 in. circumference (including lap-over for joining), $\frac{1}{4}$-in. thickness:					
482¼ square ft., at 20 lbs. to the foot .	lbs. 9645				
24 1-in. ronnd stays, 14 in. long .	„ 72				
144 ¾-in. bolts, total weight . .	„ 105				
		4	7	2	21
Carried forward		11	12	2	9

	tons	cwt.	qrs.	lbs.
Brought forward	11	12	2	9
Twelve trussed rods, containing 325 ft. of 1-in. round iron, and 300 lineal ft. of 3-in. flat bar-iron, and 24 ¾-inch bolts	1	1	0	14
Twelve 6-in. flat bars, 25 ft. long, ½-in. thickness, and 24 ¾-inch bolts	1	6	3	24
2618 square ft. on sides . . . . 1249 do. top . . . . 3867 square ft., 5 lbs. to a foot . . . . . 13,744 square ft. on sides . . . . 6,844 do. top . . . . 20,588 square ft., 4½ lbs. to a foot	49	19	3	9
Bolts and other wrought iron in connection with gas-holder, including 24 flat bars for rollers to work upon guide-rods	4	10	2	23
Tie-rods at top	6	9	1	8
	75	0	2	3
Twelve cast-iron guide-rods, 53 feet high, weight .	35	17	1	14

Estimated Cost.

	£.	s.	d.
(tons cwt. qrs. lbs.)			
Wrought iron 75 0 2 3 at £24 per ton	1800	12	0
Cast iron . 35 17 1 14 at £10 „	358	12	6
Slide carriages and valves	152	0	0
118 feet sink-pipes, 14 inches diameter, 6 tons, at £6 .	36	0	0
Two siphons	3	0	0
200 feet 14-inch pipe, to connect gas-holder with factory	62	0	6
Fitting 318 feet at 4*s.* 10*d.* per yard	25	12	4
	2437	17	4
20,000 extra would increase the holder	83	8	0
	£2521	5	4

Accidents sometimes happen from the gas-holder being filled with gas of too high a pressure, and the outlet-pipe being closed so that no escape of the gas can take place. A simple expedient in the shape of a self-acting safety-valve has been proposed in order to provide for such a case. An iron cap is suspended from a chain attached to the inside of the top of

the gas-holder. This cap covers the orifice of an open pipe standing up in the tank of the gas-holder. The top of the pipe just emerges above the surface of the water in the tank, so that when the cap is down its rim enters the water and forms a water-valve so as to prevent all escape of gas. But when the gas-holder rises above its proper height, the cap is lifted off, and the gas escapes down the pipe by which it is carried off out of the gas-holder. This contrivance is included in a patent taken out by a Mr. H. Francis, in October 1845.

CHAPTER XV.

APPARATUS FOR REGULATING THE FLOW OF GAS AND RECORDING ITS PRESSURE.

THE GOVERNOR.

This is one of those ingenious self-acting machines which are equally admirable for their efficiency and simplicity. It is placed between the gas-holder and the principal main pipe in order to regulate the pressure of gas admitted into the latter, and acts quite independently of any irregularity due to the unequal action of the gas-holder or to other causes. The governor is important also in another point of view, namely, where a town has several different stages of elevation, and where without some contrivance the pressure of gas passing through the mains would vary very much on each different stage. It has been found by experiment that the pressure in a main varies at the rate of $\frac{1}{100}$ of an inch for every foot of rise or fall.

In the case of a district lying below the works a governor is seldom necessary, the works being generally, as a matter of convenience, placed at a tolerably low level, and it is found practically that a district lying even 30 feet below the works may be lighted without the intervention of a governor to increase the pressure, as the diminution due to the difference of level would be only $\frac{3}{10}$ths of an inch of pressure. But governors are especially necessary in towns, such as Bristol, Bath, Edinburgh, Liverpool, Lincoln, Nottingham, Exeter, and many others,

which have different stages of elevation, because the gas as it reaches the higher parts of the town will act with so great a pressure as to produce very serious leakage in the pipes, besides the disadvantage of giving the upper districts an undue proportion of light at the expense of the lower. Separate governors for the regulation of pressure at different stages of elevation are not considered necessary unless the ground has a rise of about 30 feet; and in order to carry out the principle of uniform pressure to the utmost advantage, there ought to be as many governors as the quotient of the whole elevation in feet divided by 30. Every gas-work for lighting a town should have at least one governor to regulate the pressure of gas passing from the gas-holders into the first main. Many towns in flat situations which have no elevations much exceeding 30 feet will require only this one. But in other very hilly towns it would be advantageous to have several smaller governors to regulate the pressure for the different levels.

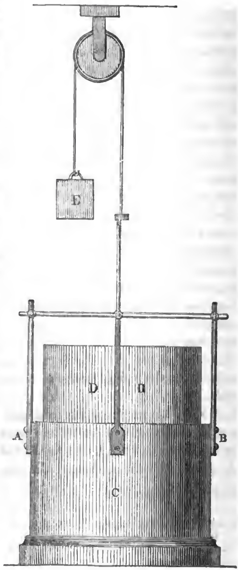
The governor is merely a miniature single-lift gas-holder suspended from the centre and furnished with an inlet and ontlet pipe, the former having a conical piston suspended in it, which regulates the admission of the gas in the inverse ratio of its pressure. The lifting part is usually a cylinder of very thin sheet iron about five times the diameter of the inlet-pipe, so as to give plenty of room for the two pipes to stand inside and leave a space above for the gas to occupy in passing through the governor. The tank is made of cast-iron plate in a circular form, usually somewhat less in depth than the diameter, and with the capacity of about 2 cubic feet for every 10,000 feet of gas required to be passed through in twenty-four hours. Thus a tank about 5 feet 4 inches diameter and 4 feet 6 inches deep will be sufficient for a governor to pass 300,000 cubic feet of gas in twenty-four hours. The lifting part, or inverted cylinder, is about the same depth and about 4 inches less in diameter. The inlet-pipe, which may be about 12 inches in diameter, is provided with a flange at the base, and is screwed to the bottom

of the tank, where it passes up in the centre through the water contained in the tank. The top of the inlet-pipe is also provided with a flange, on which is screwed an annular casting which contracts the opening to 8 inches. In this inlet-pipe is suspended a solid cone of iron 8 inches in diameter at base and about 2 inches at top. This cone is suspended from and attached to the centre of the roof of the lifting cylinder, so that the cylinder and cone rise and fall together. To the centre of the roof on the outside is attached a chain which passes over a pulley and sustains at its other extremity a weight so adjusted as nearly to balance the weight of the conical piston. It is evident that when the pressure of gas is very small, the cone descends and allows a large escape from the top of the inlet-pipe; and on the other hand, when the pressure increases, the cone will rise and contract the opening so as to cause a diminished quantity of gas to enter. Of course the perfection of this action depends on an accurate adjustment of the weight, and when once this is effected the regulation of pressure is so perfect as to leave nothing to be desired. The gas, when once admitted into the space above the inlet-pipe, of course finds no impediment to its progress, and passes off by the outlet-pipe without further hindrance. The cone is usually made of cast iron and is turned true in the lathe. The orifice at the top of the inlet-pipe is also bored true and of a conical form, so as to fit the base of the cone. The regulation of the weight and counterbalancing chain is very simple.

Let W be the weight of the cone and the lifting cylinder of the governor in air, and let W′ be their weight when the cone is immersed its full depth of 4 feet in the water. Then 4 feet in length of the chain, that is, the 4 feet measured from the crown of the pulley, must weigh $= \frac{W-W'}{2}$ and the weight of the counterbalance attached to the chain must be equal to $W-\frac{W-W'}{2}$. The reason of this will be obvious from the

same considerations as those which were employed in calculating the weight of equilibrating chain for ordinary gas-holders (see p. 209), so that it will be unnecessary to repeat them here. For example, suppose the entire weight of the cylinder and cone suspended in air be 1500 lbs., and that the weight when suspended in water is 1300 lbs., then $\frac{1500-1300}{2}=\overset{\text{lbs.}}{100}$, the weight of 4 feet of the suspending chain, or 25 lbs. per foot. The other part of the chain may be either more or less in weight than this: as it never acts to counterbalance, or rather as it acts equally on each side of the pulley, its weight is immaterial, provided it be uniform. Next, the weight of the counterbalance will be $1500-100=1400$ lbs. Now, in order to test this, suppose the cone just out of the water, and there-

Fig. 60.



fore not supported by it at all, its weight will be 1500 lbs. The counterbalance on the other side will be 1400 lbs. plus the whole weight of the chain which will then be on that side, making also 1500 lbs. Next, suppose the cone entirely immersed in the water, its weight will be 1300 plus the weight of the chain equal to 1400 lbs., which is again balanced by the counterbalance alone, the chain being now entirely on the side of the cone. Sometimes the chain is not made heavy enough to counterbalance the cone and cylinder, in which case a weight is used, which can be added to or diminished as required.

Fig. 60, drawn on a scale of 1 inch = 2 feet, is an elevation of the governor used at the Philadelphia Gas-Works. The suspended cone with the outlet and inlet pipes are not here shown, as it is believed the description already given will render the principle and details of the governor sufficiently clear.

C is the tank or outer cylinder of the governor; A and B are the attachments of the uprights supporting the cross bar through which passes the moveable rod attached to the conical piston; D D is the lifting cylinder; and E a weight suspended to the chain.

The piston has been described as a true cone turned in the lathe to this figure. It is thought to be an improvement, however, to substitute a parabolic instead of a conical form, as the exact opening of the inlet-pipe can be adjusted with much greater certainty when the parabolic form is used. This will be evident if we consider that the sections of a parabola parallel to the base decrease in direct proportion to the heights at which they are taken, whereas the sections of a true cone decrease as the squares of the heights. It follows that a parabolic piston will open or close a space in exact proportion to the height through which it is lowered or raised, whereas a truly conical piston will open or close a much larger space when the part near the base of it rises one inch than when the upper part of the cone rises through the same height. Hence

it is much easier to adjust the opening by means of the parabolic piston, which is the form always adopted by Mr. Wright for his governors.

VALVES.

The valves used in gas-works are of two kinds: namely, the hydraulic-valve, which acts on the principle of interposing a column of water in such a position and of such a depth that the gas is incapable of passing through it; and the slide or spring valve, which stops the flow of gas by the close contact of accurately planed metallic surfaces, the contact being preserved by the action of a spring, as will presently be described.

The hydraulic-valve is chiefly used in the works between the gas-holders and the mains, while the slide-valves are also extensively employed in the street mains, and are of great service in stopping the flow of gas when a part of the main is undergoing repair.

Figs. 61 and 62, drawn on a scale of $\frac{1}{20}$th of the full size, show two kinds of hydraulic-valves; and figs. 63 and 64, drawn on the same scale, show the usual form of slide-valve.

In fig. 61, D is a cast-iron cylinder, usually about 3 feet long and 16 or 18 inches in diameter. The top of this cylinder has a perfectly air-tight cover with a stuffing-box, through which works the rod D. The gas passes into this cylinder through the pipe A; the bottom part of the cylinder contains water or tar to the level *a a*, or about a foot in depth. The outlet-pipe B, through which the gas passes off to the mains when the communication is open, has its orifice about 3 inches above the level of the tar; E E is an inverted cup which covers the mouth of the pipe B, and can be raised when required by means of a pinion working into the rack on the rod D. It is evident when the cup is at the bottom and immersed in the water, as shown in fig. 61, the gas is hermetically sealed up and prevented from entering the pipe B, unless its pressure be sufficiently great to displace the water and cause it to overflow into the pipe B. In this case the gas would escape, but the

Fig. 61.

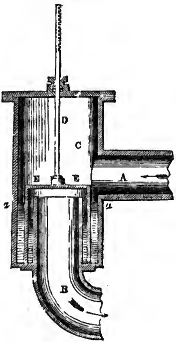
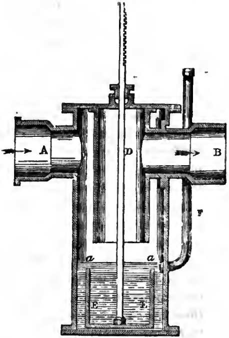


Fig. 62.



depth of 12 inches is usually sufficient to prevent this, and to afford a most effectual seal. On the other hand, it is evident when the cup E E is raised above the surface of the tar, the gas will flow uninterruptedly from the gas-holder through pipe A, and thence into pipe B, which takes it off to the main. This kind of valve is extremely simple and efficient, the chief objection to it being that the outlet and inlet pipes are at different levels, an objection which does not apply to the next kind of hydraulic-valve.

Fig. 62 is the section of a valve which is frequently made use of in the mains, where it has the advantage of acting as a receiver to contain the tar which drains off from the gas in its passage.

The outer cylinder is about 3 feet 6 inches long, and about the same diameter as in the valve last described, provided as

before with an air-tight cover and stuffing-box, through which the rod D passes: A is the inlet and B the outlet pipe, both on the same level; E E is the moveable cup, not inverted in this case, but entirely immersed in tar when at the bottom of the cylinder, and remaining full of tar when lifted up by the rod D to close the open end of the inner cylinder; the inlet-pipe A opens into the outer cylinder, and the outlet-pipe B opens from the inner cylinder. The tar should be a little higher than the top of the cup, namely, as high as the line *a a*. On the right-hand side of the engraving is a small pipe, F, with a screwed top, through which the tar is drawn off when it reaches above the level *a a*. Bearing in mind that the inner cylinder is open at the top, the action of this valve will be readily seen. When the cup is at the bottom, as in the engraving, the gas passes freely from A into the outer cylinder, then up through the inner cylinder, and goes off by the pipe B: when the cup E E is raised, however, the bottom of the inner cylinder rests on the bottom of the cup, and being of less diameter than the cup, there is an annular space of water all round, equal in depth to that of the cup; this water effectually prevents the gas from passing through it and reaching the outlet-pipe. The inlet-cylinder may be about 10 inches in outside diameter, and the clear diameter of the cup being about an inch more, a space of half an inch will be left all round, which is quite sufficient to prevent any escape of gas. It will readily be seen that when this valve is used for the street mains, the pipes A and B being laid with a slight inclination towards the cylinder, any water, tar, or oil, which the gas may contain, will drain towards the cylinder and fall to the bottom without any interference. The valve thus answers the double purpose of a receiver and that of shutting off the gas whenever required.

When this last kind of valve is used in the streets, where it would be inconvenient to have the rod D raised by means of a pinion, the rack is not cast on it, and the cup is raised by another contrivance. The rod in this case has a thread cut on it, which works through a nut in the bottom of the cup: when

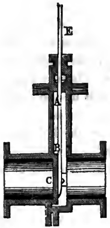
the rod is turned, the cup, being at the same time prevented from turning, is raised by the screw until it attains such a position as to seal up the bottom of the inner cylinder.

Hydraulic-valves are not much used of late years, having been superseded by an improved form.

SLIDE-VALVES.

Fig. 63 is a longitudinal section, and fig. 64 a plan in section, of this kind of valve. A B is the valve case; C is a circular iron disk attached to the rod E, which works through a stuffing-box at the top of the valve case: D is a spring which presses on the disk C, and causes it to be in perfect contact with the rim of the pipe when in its place: the disk is very accurately planed in the lathe, and the rim of the pipe is also accurately faced, as well as the part A B, against which the disk presses when raised so as to open the communication between the pipes. It is evident when the disk is placed as shown in the engraving, the passage of the gas is stopped, and when raised by means of a pinion working in a rack cast on E, the passage can be entirely opened. When used in the works, the disk is worked either horizontally or vertically, as shown in the engraving, but when used in the street, the rod E is worked horizontally, by means of a key fitting the axle of the pinion; and in this case fig. 63 becomes a plan in section, and the disk moves sideways instead of vertically, to open the communication between the pipes.

Fig. 63.



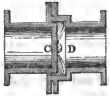


Fig. 64.

Another kind of valve has come into use in gas-works during the last few years: a disk similar to that shown in figs. 63 and

64 is pressed by a screw upon a faced rim, and when the screw is tightened, the contact is so perfect as to prevent the slightest escape of gas. When the screw is relieved, the disk may be raised so as to afford any required opening for the flow of the gas: the screw may be placed either horizontally or vertically, and this kind of valve is perhaps more correct and certain in its action than the spring slide-valve.

Mr. Clegg describes an ingenious contrivance by Mr. Lowe for intercepting the passage of gas in a main where there happens to be no valve in the neighbourhood. This is effected by filling up the main with a bladder distended by common atmospheric air, the mode of proceeding being as follows:

Supposing a fracture or joint to be repaired, for which purpose the pipe has to be taken up from a long length of main; provide two bladders, each furnished with a tube and stop-cock, then drill a hole $1\frac{1}{2}$ inch in diameter in the main pipe on each side of the place to be operated on, and insert the lower end of the empty bladder into the main: the bladder is then to be inflated through the tube at the mouth, till it expands and fills up the main, when the stop-cock is turned in order to confine the air. When the repairs to the pipes are finished, the air may be let out of the bladders, which can then be withdrawn, and the holes in the main stopped up either by means of a wooden plug or by screwing in an iron pin.

APPARATUS FOR RECORDING PRESSURE.

Various contrivances, under the name of pressure-gauges, pressure-indicators, and tell-tales attached to the clock-face of the meter, are employed in gas-works for the purpose of recording the pressure of the gas at different hours of the night and day, and also for pointing out any irregularities which have taken place in the production of gas, and consequently the working of the retorts during the absence of the superintendent.

The pressure-gauge is an instrument for ascertaining the

pressure of the gas as it flows into the mains, and consists in its simplest form of a glass tube bent in the form of a horseshoe, one extremity being open to the air and the other connected with a pipe through which the gas is passing. The tube is partly filled with coloured water, which, when no gas is pressing on the surface, stands at the same height in both legs of the tube. This height is therefore marked zero, and the tube is graduated into inches and tenths of an inch for a space of 4 or 5 inches on both sides of the line indicating zero. When the gas is admitted to the gauge, the water in one leg is depressed and in the other is raised, the pressure being equal to twice the reading on either of the legs. If the graduation were so made that 1 inch were marked 2, and so on, the pressure would be read off at once without reqniring to be doubled, and the accuracy of the gauge would be as effectually checked as in the other cases by observing that the two readings corresponded with each other. Mr. Clegg recommends a form of gauge in which the tubes are straight and connected at top and bottom by a small chamber, the advantage being that the tubes can be more easily taken out and cleaned.

The pressure-indicator is a contrivance employed with or without a governor to record the pressure at which the gas has been sent into the mains. The action of this instrument is automatic and continuous, requiring the application of clockwork to produce a uniformity of motion. There are two kinds of pressure-gauges,—namely, one in which the record is made on a sheet of paper revolving on a vertical axis, and the other made on a sheet revolving on a horizontal axis.

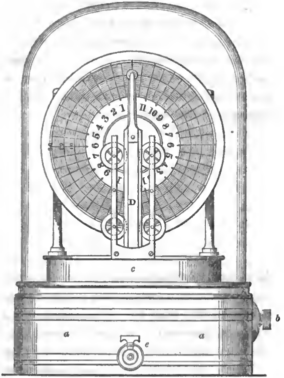
The pressure-gauge, which records on a vertical sheet, consists of an inner and outer cylinder so contrived that the latter is immersed with its mouth downwards in the water of the former. A pipe leads from the main into the outer cylinder and passes up through the water so as to admit the gas into the space enclosed between the water and the inner cylinder. This inner cylinder is so adjusted as just to float with its top

in contact with the surface of the water when no communication is open with the main. When the gas is admitted, however, its pressure causes the inner cylinder to rise. A rod carrying a pencil at the end of it is attached to the top of the cylinder and rises with it, marking the exact pressure of the gas on a sheet of paper divided into inches and tenths.

In this form of indicator the sheet of paper is coiled round a vertical cylinder which is moved by clock-work and revolves once in twenty-four hours. The paper is divided horizontally into inches and tenths, and vertically by lines which correspond with hours, so that when taken off from the cylinder the paper presents a perfect record of the pressure at which the gas has been passing into the mains during every period of the whole twenty-four hours.

The other form of recording the pressure is shown in the annexed wood-cut, fig. 65, where *a* is the outer cylinder or tank, which is entirely closed in except that there are holes in the bottom to allow the water in *a* to communicate with the water in *c*; *b* is the inlet for the gas; *c* is the cylinder, open at the top; and D is the rod carrying the pencil which marks the pressure upon a circular sheet of white paper with radiating lines which indicate the hours, and concentric circles denoting inches and tenths of an inch. The rod is attached to a float which rises and falls according to the rise or fall of the water in *c*, that is, according to the pressure of the gas in the outer cylinder *a*. The water is supplied by pouring it into the vessel *c*, which is open at the top. *e* is a pipe for letting out the water or reducing its level when required. The disk on which the sheet of paper is placed is moved by clock-work as in the other case, and revolves once in twenty-four hours, at which interval a new sheet of paper must be substituted. The sheets so marked by the pencil of the indicator become very important records and should be carefully preserved. They are used not only at the principal manufacturing works, but commonly at every station where a governor is placed. They serve to correct irregularities, to

Fig. 65.



prevent blame being imputed in improper quarters, and point out when any complaint arising from irregularity of pressure has been made, not only at what station, but at what precise hour, and under whose management, the irregularity has occurred. These records serve in the most delicate manner to check the pressure, and enable the superintendent to adjust it to the requirements of the district during the successive stages of the twenty-four hours, in which a remarkable variation takes place in the quantity of pressure required. For instance, there are some works which throughout the day scarcely require a greater pressure than half an inch, which towards the time of lighting up the streets, shops, and private houses requires to be increased to 2 or even 3 inches pressure,

and this continues till between 10 and 11, when most of the shop lights and private house lights are extinguished. Another diminution occurs about 12 o'clock, when most of the public-house lights are put out, and few lights continue burning except the street lamps. The night pressure is further diminished to its minimum about the hour when the street lamps are extinguished, and continues at its minimum low state throughout the day.

CHAPTER XVI.

ON THE GAS-METER.

The whole history of the gas-meter is one of great philosophical interest. At a very early period it became an object of very great importance, both to the manufacturers and consumers of gas, to possess the means of measuring the consumption, in order that a proper adjustment of charges might be made. The system of charging the consumer an annual rent for a certain number of burners, on the supposition that these consumed a given quantity per hour and were used daily for a certain number of hours, was found to be perfectly vague and unsatisfactory. It obviously afforded the means of so much fraud that gas companies were necessarily obliged to leave an ample margin to cover the contingencies of dishonest burning, so that the conscientious consumer was charged heavily to make up for the delinquencies of a large class who were not so scrupulous. Hence it appears perfectly natural that the great array of mechanical talent which has been from the first so active in the improvement of all kinds of gas machinery should have directed unwearied attention to the contrivance of apparatus for ascertaining with accuracy the quantity of gas burnt by each consumer. Accordingly we find the

names of all the great gas inventors amongst those who have from time to time introduced improvements in the meter.

I do not propose in this little volume to attempt anything like an account of these successive improvements, as even to glance at the several steps by which the meter has reached its present state of perfection would swell its limits to an unreasonable extent. I shall rather confine myself to a brief notice of the meters used at the present day.

These are of two principal kinds,—the wet and dry meter,—each of which has its advocates, although the opinions of gas mechanicians decidedly preponderate in favour of the wet meter. I shall only very briefly allude to the dry meter, and then proceed to a short description of the wet meter, which is far more extensively used than the other, and is generally preferred by those who have examined both kinds.

The dry meter combines in itself the principal features of two very important machines, namely, the common bellows and the piston of the steam engine.

It has been observed that the first dry meters very much resembled the bellows in their action, while the most improved forms combine a motion analogous to that of the piston in the steam engine.

The principle of the dry meter will be best understood by referring to the action of the common bellows. When the upper leaf of this well-known domestic implement is raised, a partial vacuum is produced in the interior of the bellows, whereupon the external air raises the valve in the lower leaf and enters the inside. When the upper leaf is now depressed, the valve is immediately closed and the air expelled through the nozzle of the bellows. If we now conceive the upper leaf of the bellows to be attached to clock-work so as to register the number of times which the bellows has been thus filled and emptied, it is evident, that knowing the capacity of the bellows when expanded, we obtain the means of measuring the quantity of air which has passed through.

Now in the dry meter, gas is measured by the alternate ex-

pansion and contraction of a chamber which may very aptly be compared to the expanding and contracting chamber of the bellows. This chamber varies considerably in its shape in different kinds of meters. For example, in Defries' meter there are three measuring chambers, separated from each other by flexible partitions of leather, which are strengthened by metal plates. When the chambers are in a contracted or collapsed state, the leather disks are upright and parallel, but when expanded by gas, they assume a conical form, which produces the enlarged or expanded form of the chamber. The alternate motion of the flexible disk, as it forms a cone first on one side of its vertical axis and then on the other, is communicated by wheel-work to the measuring machinery. It was found when only two flexible partitions were used in this kind of meter that the lights were liable to oscillate, a defect which is remedied in a great measure by having three measuring chambers, the gas being admitted into these and passing off from them by means of an ingenious system of valves, which are opened and closed by the same power which registers the measurement,—namely, that of the gas itself.

Another form of dry meter is that used by Messrs. Croll and Glover, in which metallic disks are used, and these move always parallel to each other and in a perpendicular direction. For a ten-light meter the area of the disk is usually made 10 inches, the height of the measuring chamber being about 12 inches, and breadth about 7 inches. This rectangular space is divided into two parts by a partition parallel to the disks, one of which works on each side of the central partition. Each of the disks is connected to the central partition by a flexible band of leather attached to the circumference of the disk, so as to allow it to move freely backwards and forwards. During the motion of the disks they are kept upright and parallel to each other by a combination of jointed rods placed behind them. The two measuring chambers of this meter are formed by the space between the central partition and the disk on each side of it, and the accuracy of the measurement depends

on the regular and uniform expansion of the flexible band which forms the side of the chamber, so that the capacity of the chambers shall be invariably the same every time they are expanded.

The action of the metallic disks in this meter has been compared to that of the piston in a steam engine, and there is certainly a considerable analogy if the comparison be made with the horizontal cylinders of a locomotive engine, in which the motion of the piston is precisely the same as that of the disks in this kind of meter. The system of slide-valves for admitting the gas to the inside and outside of the cylinders and to the exit pipe is extremely ingenious, and consists of a double series of apertures, two of which lead respectively to the inside and outside of one chamber, while the third in each series communicates with the exit pipe from each chamber.

There are many other makers of dry meters besides the two firms which have been mentioned, but the difference in the form of meter manufactured is generally very slight, and the principal modifications of the dry meter are those which have just been noticed. It does not fall within our province to make any comparison between the different forms of dry meter, and we therefore proceed to the consideration of the wet meter.

THE WET METER.

The most complete form of meter is the ordinary consumers' meter, which is made of various sizes, suitable for three lights and upwards, and contains several contrivances for shutting off the supply of gas under certain circumstances and for regulating the height of the water, which are not necessary in the large station meters.

By reference to figs. 66 and 67 the general forms of the consumers' meter will be understood. Fig. 66, on a scale of one-fourth of the actual size, is a section parallel to the front of the meter, showing the receiving chamber cut in two. Fig. 67, on the same scale, is a cross section through the meter,

Fig. 67.

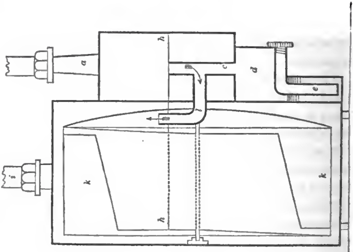
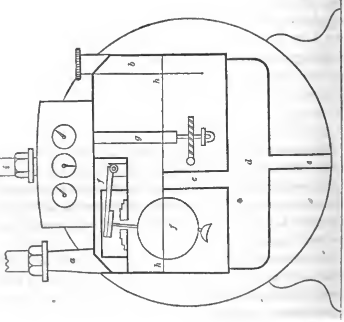


Fig. 66



showing both the receiving chamber and the wheel-case in which the meter-wheel revolves.

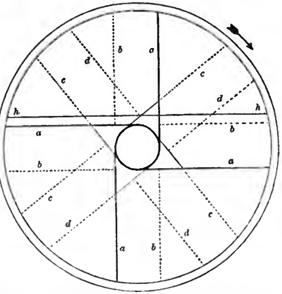
The receiving chamber is provided with an inlet-pipe *a*, a pipe *b* with a top which unscrews for the purpose of admitting water to the meter, a waste-pipe *c*, the top of which is level with the exact height at which the water is intended to stand, and so placed that the meter cannot be filled with water above this level: *d* is the waste water box, and *e* a pipe, the lower end of which is sealed by dipping into water, and which serves to draw off the water from the waste water box without allowing any of the gas to escape; *f f* is a lever-valve acted on by a ball-float and fixed in a perfectly air-tight box, so that no gas can enter the receiving chamber unless the float is buoyed up at such a height as to lift the valve into the position shown in fig. 66; *g* is the upright shaft which carries the wheel-work for giving motion to the hands of the dial, and is worked by a spiral worm on the axis of the meter-wheel which gives motion to a wheel at the base of *g*; *h h* is the level of the water, and *i* is the pipe by which the gas leaves the meter and goes off to the burners: *l* is the inlet-pipe by which the gas passes from the receiving chamber into the wheel-case.

In fig. 67, *k k* is the wheel-case, and the other letters of reference indicate the same parts as in fig. 66.

The only point of any difficulty in the meter is the construction of the wheel, and this from its peculiar shape is by no means easy to describe. It may be defined as a hollow cylinder, somewhat less in diameter than the wheel-case, constructed of very light sheet metal, and provided with a hollow axis whose diameter is about one-seventh that of the cylinder itself.

The space between the axis and the inner periphery of the cylinder is divided into four chambers, the planes of division being placed obliquely to the face of the wheel, which has been compared to a four-threaded Archimedean screw. In fig. 67 the trapezoidal form of one of these chambers is seen, and fig. 68 is a front view of the wheel in which the inlet-slits,

Fig. 68.



through which the gas is admitted to the chambers, are shown by the full lines *a a*, &c. The dotted lines marked *b b*, &c. show the outlet-slits on the other side of the wheel, while each pair of lines marked *c d* shows the position of one of the oblique division plates which complete the chambers.

These wheels are of course made with great accuracy, because on the exact capacity of the four measuring chambers, as bounded on one side by the water and on all other sides by the metal plates, depends the correct registration of the wheel.

The action of the meter will now be readily understood: the gas entering into the receiving chamber passes through the pipes *c* and *l* above the level of the water at *h h* into the interior of the wheel, when it enters that chamber whose inlet-slit happens to be above the surface of the water. Having filled this chamber and overcome the very trifling resistance of the wheel arising from the friction of its bearings and of the part moving through the water, it causes the wheel to revolve, while at the same time an outlet-slit is rising up on the other side of

the wheel, through which the gas escapes into the case and passes off through pipe *i*. The train of wheel-work giving motion to the hands on the dials is very simple, each pinion working into a wheel containing ten times as many teeth as itself: the ordinary dials register hundreds, thousands, and tens of thousands, the whole of which are actually indicated, while the parts of a hundred feet are read by estimation.

It was formerly objected against gas companies that frauds were practised on the consumers by keeping the water too high in the meters, whereby the capacity of the measuring chamber was diminished, and the whole effect produced of dealing out short measure to the consumer. Meters, however, constructed on the principle shown in our engraving cannot be tampered with in this way, and provided the waste-pipe be once properly adjusted at the correct height to correspond with the capacity of the chamber, the meter must ever afterwards register correctly in this particular. On the other hand, the gas company is effectually protected against fraud on the part of the consumer by means of the float-valve, which will immediately close and prevent all admission of gas, should it be attempted to let out the water for the purpose of enlarging the measuring chamber, or causing the gas to pass through without turning the wheel at all.

Frauds are sometimes practised by tilting the meter on one side, but this experiment is so dangerous as to deter any but a very determined rogue from attempting it. Generally speaking, the gas companies by their power of inspection and other privileges are sufficiently protected, and I believe that frauds occasioned by consumers tampering with the meters are now of rare occurrence.

The whole of the preceding description applies to the consumers' meter, which is made of all sizes, with drums or wheels varying from 10 inches up to 60 inches, and calculated to measure the gas for any number of burners from three to eight hundred.

Station meters are now commonly made with wheels exactly

the same as that described for the consumers' meter. The station meter, however, is much simpler, being merely provided at the back with an inlet and outlet pipe for the gas, both of which open at once into the meter-case. It has also water-gauges, by which the height of the water can always be adjusted to the proper level.

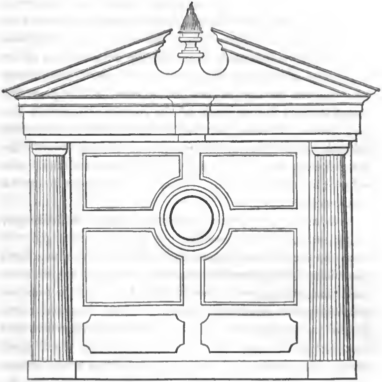
The station meter, however, contains none of the apparatus marked *c d e f* in figures 66 and 67. The shaft of the meter-wheel carries a pinion which forms the first of the train of wheels giving motion to the hands on the dials. Station meters are now made of very large capacity. Mr. Wright has recently erected one at the Western Gas-Works which registers 400 feet at every revolution, and as the best speed is 100 revolutions per hour, this meter is capable of measuring 40,000 feet of gas per hour. The same gentleman has also erected a station meter in Dublin which is said to be one of the largest in the world, and capable of registering 50,000 cubic feet per hour.

Fig. 69 is an elevation on a scale of 4 feet equal to 1 inch of the station meter at the Western Company's Works. The diameter of the wheel is 9 feet 9 inches, and its breadth 8 feet. The inlet and outlet pipes are each 14 inches in diameter.

The dial face of a station meter usually contains six dials, the hands of which register in succession from hundreds up to ten millions. Besides this, the dial face has a clock, to the minute hand of which is attached a rod carrying a pencil, which indicates the working of the meter, or the production of gas at each period of time throughout the twenty-four hours.

This contrivance, which is called the tell-tale, requires the dial on which the pencil works to revolve on its axis; and the dial has also attached to it a sheet of paper divided into twenty-four parts, to correspond with half-hours, and also frequently having two or more concentric circles marked on it. An inspection of the sheet of paper so marked at once shows whether the production of gas has been regular and progressive

Fig. 69.



at all hours both of night and day, so that it affords the superintendent a good check on the workmen during his absence.

CHAPTER XVII.

DISTRIBUTION OF GAS.

ON THE CHOICE OF A SITE FOR GAS-WORKS.

In the largest class of towns the favourite locality for gas-works has generally been the side of a river or canal, which commonly furnishes an advantageous level, and at the same time gives

the convenience of water carriage for the supply of the coal, the principal heavy article concerned in the manufacture of gas. Since the general establishment of railways, however, in nearly all the civilized countries in the world a site contiguous to the railway is frequently found equally advantageous as far as economy of transit is concerned. The level of the railway being seldom so low as that of a river, which generally follows the very lowest levels of the country, a necessity has been created for laying some of the mains with a downward inclination, and this necessity has drawn inquiry towards the circumstances under which this may be done, and the limits within which districts lying below the site of the works can be advantageously supplied with gas.

It can scarcely be necessary to remark that a fluid like gas, having seldom half the specific gravity of common air, will always have a tendency to ascend in pipes. Two consequences follow immediately from the relative lightness of gas as compared with common air,—namely, that except for the pressure with which the gas is sent into the mains, it would never descend in any pipe, and, in fact, would scarcely travel in a horizontal main; and, secondly, it follows that the highest lights in any district, and even in an individual house, always burn with more brilliancy than the lower ones, because at the greater elevation the gas has less resistance to overcome, so that it issues from the burners with more force and buoyancy.

In large towns where extensive gas-works are to be erected in suburban situations, it is very desirable to select the neighbourhood of a railway and to lay down a branch line of rails communicating with the retort-house. The Central Gas Consumers' Works at Bow Common afford an instance of this arrangement. A branch railway is there laid down connecting the works with the railways which serve for the supply of coal. The rails are laid actually into the retort-house, so that the coal-waggons are brought immediately in front of the retorts. The rails are elevated a sufficient height above the ground to allow the waggons to tip with perfect ease, so that

nothing can exceed the convenience and economy of the arrangement for supplying the coal for the retorts.

It is probable that similar connections between gas-works and railways will be made whenever, in future, new establishments are called for in the neighbourhood of large towns. Already many towns of minor importance are being favoured with an establishment for gas-making, owing to the proximity of a railway station where coals can be delivered alongside without the expense of carriage on ordinary roads. The railway companies would do well to encourage the establishment of gas-works even for very small towns, as in addition to the traffic in coal which it produces, they obtain the advantage of lighting their stations by gas. The most eligible situation for erecting gas-works close to a railway station is where the railway is on an embankment 12 or 14 feet high. A siding should here be constructed, on which the coal-waggons turn out of the main line and discharge their contents through shoots or other well-known contrivances. The retort-house should be erected as close to the siding as convenient, so that the coal as delivered from the waggons will be quite ready for charging the retorts, and all expense, both of carting and wheeling the coal, will be avoided. In the north of England this juxtaposition of gas-works and railways is by no means uncommon, and many small towns are reaping the advantage of lighting by gas which might otherwise have long been without so great a blessing.

There are many other circumstances besides the facilities for distributing the gas and those connected with the conveyance of coal which must enter largely into consideration in the choice of a site. These circumstances frequently arise out of the relative value of property and the means of acquiring it, and become so purely of a local nature that no general observations would have any value as applied to them. A dry situation is of course highly desirable, as many of the pipes and connections are under-ground and would be much interfered with by water. During the late disastrous floods many

gas-works have suffered very much from the ground being submerged in water, and in such cases the towns depending on them have had to submit to a state of total darkness for some nights and even weeks. Considerations of this nature, and also those connected with the solidity of the ground and its proper capacity to sustain the buildings to be erected, will naturally occupy the attention of the Engineer in laying down a design for new gas-works.

It is very important to have a good map, not only of the site of the works but of the whole district to be supplied with gas; on this map the course of all the mains should be laid down, and the position of all governors, siphons, and water receivers should be marked.

In addition to a mere surface plan, a network of levels should be taken over the whole district, and the grades or inclinations of all the mains marked on. The relative elevations of the whole district with reference to some fixed point near the gas-holder would be best shown by contour lines of equal heights drawn throughout the district. When the town is nearly all on the same level, contour lines may be laid down at intervals of a foot or 18 inches of vertical height, but where the streets are very steep, intervals of 3 or 4 feet would be sufficient. The best rule for laying on the contours is, that they ought to be so frequent as to show by a mere inspection of the map the level of every part of the surface with reference to the fixed datum point.

The admirable surveys of towns made under the directions of the Officers of the Corps of Royal Engineers, and plotted on a scale of 5 feet to 1 inch, are exceedingly well adapted for the delineation of gas and water pipes. The further information relative to the levels of the streets, the inclination of the mains, &c. will be readily added by a competent person, and will constitute the map a very valuable instrument in the hands of the Gas Company. There are no doubt abundant examples of the same kind of mistakes made by Gas and Water Companies as by Commissioners of Sewers for want of proper

maps delineating their under-ground works. Much economy and efficacy may be expected where the circumstances of each district as to levels and pressure can be at once ascertained, while on the other hand great losses are frequently occasioned by an ignorance of such particulars. It has been asserted by a writer on this subject that in a street of half a mile in length not less than twelve receivers have been discovered on taking up the main, while one, or at most two, would have been sufficient to drain the main. Blunders of this kind are evidently occasioned by the want of maps to refer to, showing the works already executed, and which would have rendered unnecessary the repeated reconstruction of the same works.

ON THE LAYING OF MAINS FOR DISTRIBUTING GAS.

In wide streets mains are frequently laid on each side, and they must be laid of such a depth as to be out of the reach of frost, usually from 1½ to 2 feet below the surface of the ground. Wherever the main, in following the irregularities of the surface, has a depression formed in it, a siphon or water-receiver becomes necessary to allow the water to drain from it, and this siphon will also receive any condensed water which might otherwise lodge in the pipes and obstruct the flow of gas.

These water-receivers are generally made twice the diameter of the main, with a depth equal to four times the diameter of the main. When the mains are in good order and free from leakage, the quantity of water collected in the receivers is very inconsiderable, and does not require to be removed more than once a year, except in very wet weather. When the main is leaky, however, not only does the atmospheric air enter, but water also penetrates, and the receivers become very soon filled.

Gas mains are usually cast in lengths of 9 feet, with a socket at one end and a plain semicircular bead at the other. The length of the socket is usually about 4½ inches, and its

diameter from $\frac{3}{4}$ to an inch larger than the outside diameter of the pipe, so as to leave a space of from $\frac{3}{8}$ to $\frac{1}{2}$ an inch between the pipe and the socket when laid together. Pipes up to 3 inches diameter are usually made with $\frac{1}{4}$ inch thickness of metal, from 3 to 6 inches with $\frac{3}{8}$ inch, from 6 to 10 inches with $\frac{1}{2}$ an inch, from 10 to 13 inches with $\frac{5}{8}$ inch thickness, from 13 to 15 inches with $\frac{3}{4}$ of an inch, from 15 to 18 inches with $\frac{7}{8}$ inch, and so on; the open end of the socket being sometimes strengthened a little beyond these dimensions.

Mr. Clegg recommends that the mains should be proved by the pressure of a column of water equal to 250 or 300 feet high, and if any moisture be detected on the outside, the pipe should be examined for cracks or flaws, and if these exist it should be at once rejected. A sound pipe will generally be distinguished from an imperfect casting by the ringing sound which it gives out when struck smartly with a hammer.

The joints of gas mains are usually made in London with tarred gaskets of spun-yarn driven into the socket for about half its length, and the remaining opening filled with lead, which is well driven in with a blunt caulking iron. When the gaskets are first well soaked in hot pitch and tallow, and the joint well smeared over with pitch, this kind of joint is said to answer well.

Mr. Clegg, however, describes another mode of making the joints without lead, which was used successfully in laying the pipes for the Atmospheric Railway, and which he prefers on account of the greater elasticity in the joint than where lead is used.

This joint is made by caulking "into the bottom of the socket, to the depth of about 2 inches, white rope-yarn well covered with putty; then at the lip of the socket caulk in tarred gaskets, of such a thickness that it will just fit into the annular space left between the pipe and the socket, and to such a depth that a space of about $1\frac{1}{2}$ inch will be left between the two yarns all round the pipe. At the top of the socket where the ends of the tar gaskets meet, draw up a portion to form a

'gate,' exactly in the same way as for running a lead joint: take two parts of melted Russian tallow and one part of common vegetable oil, and pour the mixture while it is warm into the 'gate;' it will run into and fill up the space between the two yarns. As the mixture does not contract on cooling and is quite impervious to the air, it must form an air-tight joint."

A very superior plan of jointing pipes has been used for some years in Liverpool and Manchester, which is found highly successful when the pipes are laid in straight lines or in curves of large radius. In this method the socket of the pipe is bored with a slightly conical opening, and the small end turned with a similarly conical figure to fit the socket. The two ends of the pipe are covered with a mixture of white and red lead, and being brought together are driven home by blows of a mallet. It is said that this joint is perfectly tight, and that no change of temperature will cause it to leak. This method of making the joints has been adopted wherever practicable in laying the mains of the Philadelphia Gas-Works.

It has lately been proposed to use vulcanized India-rubber rings between the joints of water and gas pipes, and an able Report, very much in favour of this material, has been made by Mr. Wicksteed, Engineer to the East London Water-Works. In applying India-rubber rings to the joints the socket end is cast as usual to receive the spigot end of the pipe; the spigot end, instead of being cast with a plain narrow bead, has a band or fillet cast on it at the extremity, and a similar band surrounding it at about 3 or 4 inches from the end. Between these two bands rests the circular ring of India-rubber, which is stretched over the spigot end of the pipe ready to be inserted in the socket. These bands may project beyond the outer diameter of the spigot end about a quarter of an inch all round for pipes up to 12 inches diameter, and generally they project a little more than half the diameter of the India-rubber ring. Between the bands and the inside diameter of the socket there is a play of about a sixteenth of an inch all round, and sup-

posing the band to project $\frac{3}{16}$ths of an inch, it is evident that the India-rubber ring must be compressed into a thickness of a quarter of an inch, while its breadth is considerably more than this. The compression causes the India-rubber ring to assume the shape of a flat belt, always striving to regain the circular form, and therefore exerting an immense resistance against any pressure employed to displace it. Mr. Wicksteed, in a comparison between the cost of lead joints and those made with vulcanized India-rubber, deduces a considerable saving in favour of the latter. As there was some doubt whether this material would resist the action of certain chemical agents contained in coal gas, the opinion of Mr. Aikin was requested on this subject. It was known that naphtha, one of the products of distillation frequently found in coal gas, was capable of dissolving caoutchouc, but Mr. Aikin reports that naphtha has no other effect on vulcanized caoutchouc than that of causing it to swell, which would obviously rather increase the soundness of the joint than otherwise. He also observes that the resistance or spring of vulcanized India-rubber is far more complete than that of unvulcanized caoutchouc, and that the elasticity of the former is much more durable. On the whole, the opinions of Mr. Wicksteed and Mr. Aikin are decidedly in favour of the employment of caoutchouc rings for the joints both of water and gas pipes.

Although there are no very definite or exact determinations on the subject, it seems to be generally admitted that gas should flow out of the holders with a pressure of $1\frac{1}{2}$ to 3 inches head of water, and should proceed along a main till it reaches a point for distribution, where Mr. Clegg recommends an equilibrium cylinder to be fixed. No supply whatever should be taken from the main till it reaches this cylinder, which should be fixed at a place where several streets diverge, and where consequently more than one main is required.

The supply of gas from this cylinder should, according to Mr. Clegg, be so regulated as to cause the gas to flow into the branches at a pressure of half an inch of water.

Adopting this view, we shall be able to estimate the irregularity in the inclination of the pipes which would be overcome by the pressure at the equilibrium cylinder. It is evident that with a depression of less than 50 feet the whole pressure at the equilibrium cylinder would be absorbed, and the gas would not move at all. Practically the limit of depression which may be safely resorted to is much less than this, and 25 feet will probably be as great a depression as would in any case be judicious, and even with such a depression as this it would be better to have the pressure at the equilibrium cylinder somewhat more than half an inch.

Mr. Clegg recommends, wherever practicable, that the main pipes should be connected to each other by cross pipes, which produce the effect of equalizing the pressure of the gas at every point. Where this is not practicable, and where the irregularities of the district to be lighted are considerable, he recommends the use of a governor to reduce the pressure in the higher districts. It is generally considered that a governor is necessary when a difference of level equal to 30 feet exists, so that there are many towns which would require several governors in order to make the pressure uniform or nearly so in all the mains.

ON THE LEAKAGE OF MAINS.

This is a subject of great importance, and one which varies so much under different circumstances as to produce great influence on the returns of gas companies. Where every degree of foresight aud economy has been exercised in the actual manufacture of the gas, it may afterwards be so much diminished by leakage between the gas-holder and the meters of the consumers as to reduce the profits of the company to an alarming extent. The amount of leakage is variously estimated at from 10 to 30 per cent. Many gas managers insist, that when the mains are properly laid and the joints properly made, the loss by leakage should not exceed 10 per cent.

Mr. Croll in his parliamentary evidence estimated that one-sixth of the whole gas sent out would be absorbed by leakage and stealage. Besides these sources of loss, there is a dimiuution of gas by condensation in passing through under-ground mains at a low temperature.

Mains are now made in a very superior manner, and the oldest gas-works are those in which the most extensive leakage prevails. There is also reason to suppose that the pipes are now cast in a superior manner, the metal being closer and more solid in texture, so as not to admit of so much leakage as that which prevails in porous and imperfect castings.

It is remarkable that although gas in passing through the mains is always under a certain pressure which is generally supposed favourable to leakage, yet Professor Graham has found on examining the gas that as much as 25 per cent. of atmospheric air has penetrated the pipes and mingled with the gas. This is an instance of that curious process termed by chemists *endosmose*, by virtue of which gases will pass through solid barriers and enter into a state of mixture with each other. Professor Brande is of opinion, that in common coal gas, ammonia and some of its compounds are probably concerned in some of the curious phenomena of exosmose and endosmose. The peculiar penetrating properties of ammonia are well known, and the Professor thinks that the fetid odours which accompany gas mains and pervade the soil surrounding them are more attributable to the escape of ammonia than to the tar and naphtha which have hitherto been supposed to cause them.

Not only is such a mixture of coal gas and atmospheric air frequently effected, but there are many instances in which gas has been known to enter water-pipes to the great injury of health, and even to the danger of explosions, which have more than once been occasioned through this cause.

The porosity of cast iron has long been a well-ascertained fact, and numerous experiments have been quoted to show that under high pressure even water may be forced through

its pores and made to appear as a damp film on the outside of pipes. It is also certain that ordinary cast-iron pipes are permeable by gas, as the soil in contact with gas-pipes is almost invariably found to be saturated with gas, nor is the saturation confined to the joints, but continuous throughout the length of the pipes. These facts render it evident that great attention should be paid to the quality of the cast iron of which the pipes are composed, and that the pipes themselves should be tested by a pressure of water as in the case of water-pipes. Much greater attention is also now paid to the joints, which are made in a very superior manner to that formerly in use.

The effect of too great a pressure on the gas when delivered into the mains tends considerably to increase the leakage. Mr. Low mentions a case in which a loss of 75 per cent. of all the gas made was sustained by the Company, and this great loss he states was principally due to a pressure of 2 inches head of water which had been kept on the pipes. As soon as this pressure was diminished, the leakage was very considerably reduced.

The loss of gas by leakage from the pipes is something enormous. Even by those who are remarkable for the closeness and illiberality of their estimates it is computed at 10 per cent. of the whole quantity produced, whilst it is frequently estimated as high as one-third of the whole quantity when it serves the interests of the existing gas companies to put their expenses as high as possible for the purpose of preventing competition, reducing their parochial taxation, and other similar occasions.

There can be little doubt that a great part of the gas lost in this way arises from the present vicious system of managing the streets in large towns. Three powerful interests, the Sewers' Commissioners, the Water Companies, and the Gas Companies, exercise an independent control over the subterranean thoroughfares of the metropolis, and one or other powerful company is perpetually tearing up the streets in

order to repair their old works or construct new ones. The gas mains and service-pipes may be seen meandering underground interwoven with the water-pipes whenever the surface is broken up and a foot or two of earth removed. Commonly a peculiar stench reveals the escape of gas whenever the pipe is exposed, but independently of this, the soil saturated with black carbon and other matters left by the gas in percolating through it proclaims the fact that in all the public streets a very serious leakage of gas is daily and hourly taking place. The remedy for this and a hundred other evils connected with the present system is to have all the sewers, water-pipes, and gas-pipes laid in an arched gallery or passage, to be made under every street, wide and large enough to carry all the various trunks required for sanitary and other economical purposes in large cities. Every improvement, like the Electric Telegraph, requiring under-ground wires to be laid down, affords an additional argument in favour of such a provision.

To this passage or gallery there should be ample means of access, and permission to traverse it at all times should be afforded to the various agents of public and other companies whose property is laid down under-ground. Public officers should also be appointed to inspect all the sewers, water-pipes, and gas-pipes which traverse the galleries, to see that all repairs are immediately executed and that no leakage occurs in any of them. If this plan were carried out, I believe the sanitary interests of the metropolis would be enormously benefited, and the present wicked waste of gas in a great measure prevented, as all leaks would soon be discovered and repaired.

At the same time it must be admitted that some part of the loss which takes place in gas passing through street mains is unavoidable, and can scarcely be guarded against by any precautions. Amongst these is the loss caused by condensation, which is said at some works to amount to a very considerable portion of the whole deficiency. Working at a high pressure should be avoided if possible, as it contributes considerably to

the leakage. Nevertheless, there are many instances, as that of the Great Central Gas Company and that of the Western Gas Company, where a pressure of from 2 to 4 inches of water is required in consequence of the great distance from the works to the districts which they supply.

ON THE FLOW OF GAS THROUGH PIPES.

In determining the size of main pipes capable of distributing given quantities of gas, it is necessary to combine certain empirical results derived from experiment with certain laws applicable to the movement of fluids. The modes of calculation usually resorted to for determining the dimensions of mains will be more simply discussed by dividing the subject under three separate heads: 1st, the motion of gas through simple orifices; 2nd, its motion through horizontal pipes; and 3rd, its motion through pipes varying from the horizontal direction.

I. Motion through simple orifices.

The theoretical laws which apply to this case are the following:

1. The velocity with which gas issues out of a simple orifice is as the square root of the head of water by which it is pressed. The gas in this case follows the same simple law as water itself; and as the pressure applied to gas is usually estimated in inches of water, it is convenient to use this law in the form here expressed. Of course the quantity of gas discharged through any orifice being in proportion to the velocity, all other things being alike, it follows that the quantity of gas passing through any simple orifice is as the square root of the pressure.

Let H be the height or depth of water in inches denoting the pressure on the gas, and let Q be the quantity of gas discharged through any orifice with that pressure. Let h be any other depth of water, also in inches, for which it is required to ascertain the quantity q. Then

$$\sqrt{H} : \sqrt{h} :: Q : q \text{ or } \frac{\sqrt{h}\,Q}{\sqrt{H}} = q \quad . \quad . \quad . \quad . \quad (1)$$

In order to illustrate this, it may be stated that the quantity discharged under 4 inches head of water will be twice as much as under 1 inch. The quantity under 9 inches will be three times as much as under 1 inch; and in the same proportion for any intermediate pressures.

The rule may be thus expressed in words. Multiply the quantity of gas delivered under the pressure of any known depth of water by the square root of the depth for which the quantity is required, and divide the product by the square root of the depth for which the quantity is known, the quotient will be the quantity delivered under the required pressure.

Suppose it has been ascertained by experiment that under a pressure of 3 inches of water 400 cubic feet of gas are discharged per hour through a certain opening, it is required to know how many cubic feet of the same gas will be discharged through the same opening with a pressure of 2 inches of water.

Here $\frac{\sqrt{2} \times 400}{\sqrt{3}} = \frac{565 \cdot 6}{1 \cdot 732} = 327$ cubic feet, the quantity required.

2. The pressure remaining constant, the quantity of gas discharged through a simple orifice will be inversely as the square root of its specific gravity. It is evident that the lighter gas will flow out with a much higher velocity than the heavier, and the exact proportionate velocity of the two has long been proved to follow the law just quoted.

Let G be the specific gravity of a gas whose rate of delivery through any orifice in a given time is equal to Q, and let it be required to find the quantity q which will be delivered under the same circumstances when the gas has a specific gravity equal to g.

$$\text{Here } \sqrt{g} : \sqrt{G} :: Q : q \text{ or } \frac{\sqrt{G}\,Q}{\sqrt{g}} = q \quad . \quad . \quad . \quad (2)$$

Suppose it were known that cannel coal gas of specific

gravity ·550 were delivered out of an orifice at the rate of 400 feet per hour, and it is required to ascertain the rate at which a very light inferior gas of specific gravity ·360 would pass under the same pressure through the same orifice.

Here $\frac{\sqrt{\cdot 550} \times 400}{\sqrt{\cdot 360}} = \frac{296 \cdot 64}{\cdot 6} = 494$ cube feet per hour, the quantity which would be delivered of the lighter gas.

3. The pressure and specific gravity remaining constant, the discharges of the same gas through different openings are as the areas of the openings, or as the squares of their diameters. Thus, all other circumstances being alike, an orifice of 2 inches diameter will discharge four times as much gas as one of 1 inch. An orifice of 3 inches diameter will discharge nine times as much; and so on.

This rule is not strictly correct in practice, being based on the theoretical supposition of an entire absence of friction. Since there is less proportionate friction in a large opening, the discharge in practice is more than that assigned by theory for large openings. Many gas engineers, however, have estimated the size of their mains according to this law, and have not thought it advisable to reduce the size below that given by theory, because the excess allows for errors and imperfections in laying the pipes, and for other contingencies which may obviously arise.

Let D be the diameter of any orifice through which the quantity Q can be discharged, then the quantity q which will be discharged through any other opening of the diameter d will be

$$\frac{d^2 Q}{D^2} = q \quad . \quad . \quad . \quad . \quad . \quad (3)$$

For example, suppose 1000 feet of gas are discharged per hour through an orifice half an inch in diameter, required the quantity of the same gas which would be discharged through an orifice $4\frac{1}{4}$ inches diameter.

Here $\frac{4 \cdot 25^2 \times 1000}{\cdot 5^2} = \frac{19062}{\cdot 25} = 76248$, the quantity discharged

through the larger orifice. It is probable that several hundred feet more would be actually discharged than the quantity determined by theory, for the reason already stated.

We now come to the combination of practical results with the theoretical rules which have been laid down for determining what Mr. Clegg very properly calls the *initial* velocity of the gas, that is, the velocity with which it commences to flow through an opening, as distinguished from its velocity after passing through a main pipe of greater or less length. It is to be regretted that the practical experiments by which theory is to be compared, and in some cases modified, are here very scanty and insufficient. Mr. Clegg gives a Table showing the quantities discharged through a very small circular orifice of only one-fourth of an inch diameter at different pressures, from half an inch up to 5 inches. On calculating the quantities which ought to be discharged in proportion to the discharge under the lowest pressure, the results are sufficiently near, as will be seen from the following comparison:

Table of the quantity of carburetted hydrogen gas of specific gravity ·420 *which will flow per hour through a circular orifice of one-fourth of an inch.*

Pressure.	Quantity of Gas by experiment, in cubic feet.	Quantity of Gas by calculation, in cubic feet.
½ inch	80·	
1 "	113·	111·7
2 "	160·5	160·
3 "	195·	193·1
4 "	226·	226·2
5 "	253·	253·

Mr. Clegg has also another Table showing the quantity of gas of specific gravity ·420 discharged by experiment and

calculation where the pressure remains constant at half an inch and the diameter of the orifice varies from one-fourth of an inch up to 6 inches.

Diameter of orifice in inches.	Quantities of Gas discharged in cubic feet per hour.	
	By experiment.	By calculation.
·25	80	
·50	321	320
·75	723	720
1·00	1287	1280
1·125	1625	1620
1·25	2010	2000
1·50	2885	2880
6·00	46150	46080

The excess in the experimental results is accounted for by the proportionate diminution of friction, as already explained.

Assuming the primary experiment giving 80 cubic feet of gas of specific gravity ·420 discharged through one-fourth of an inch orifice under a pressure of half an inch to be strictly correct and worthy of forming a basis, let it be required, by way of illustration, to determine the quantity of gas of specific gravity ·500 discharged per hour through a circular orifice 4 inches in diameter under a pressure of $2\frac{1}{2}$ inches of water.

First, To find the diminished quantity due to the increased specific gravity, we have

$\frac{\sqrt{\cdot420} \times 80}{\sqrt{\cdot500}} = \frac{51\cdot84}{\cdot707} = 73\cdot3$, the quantity discharged of specific gravity ·500.

Secondly, To find the increased quantity due to the larger orifice, we have

$\frac{16 \times 73\cdot3}{\cdot25^2} = \frac{1172\cdot8}{\cdot0625} = 18765$, the quantity of gas having a

specific gravity = ·500 discharged through a circular orifice 4 inches diameter.

Thirdly, To find the increased quantity due to the pressure of $2\frac{1}{2}$ inches, we have

$\frac{\sqrt{2\frac{1}{2}} \times 18765}{\sqrt{\cdot 5}} = \frac{29649}{\cdot 707} = 41936$, the required quantity of specific gravity ·500 which will be discharged in one hour from a 4-inch circular opening under a pressure of $2\frac{1}{2}$ inches of water.

We now come to the second and more important practical inquiry, namely, that of determinining the quantities of gas which will flow through mains of given length and area.

Mr. Clegg quotes a series of six experiments, in which gas under a pressure of half an inch head of water was made to flow through various lengths of 6-inch pipe up to thirty-four yards. From these experiments he deduces the law that the quantities of gas discharged in equal times by a horizontal pipe under the same pressure and for different lengths are to one another in the inverse ratio of the square roots of the length. Taking as a basis Mr. Clegg's first experiment, which gave a discharge of 44,280 feet per hour through a pipe 3·46 yards long, we shall find the quantity discharged through a pipe 34·20 yards long by this proportion,

$\sqrt{34\cdot 20} : \sqrt{3\cdot 46} :: 44280$: required quantity;

or $\frac{44280 \times \sqrt{3\cdot 46}}{\sqrt{34\cdot 20}} = \frac{82361}{5\cdot 848} = 14083\cdot 6$ cubic feet, while the quantity actually discharged by experiment is 14,080 cubic feet, an experiment sufficiently accurate for all practical purposes. This mode of calculating the discharge, although founded on a very scanty basis, appears to be the only one made use of by Mr. Clegg. Putting P for the product of the discharge through a 6-inch pipe by the square root of 3·46 yards the length of the pipe, and L the length in yards of any other 6-inch pipe, the discharge per hour through L will be equal to $\frac{P}{\sqrt{L}}$, and as in this case the value of P is known, being $= 82361$, the form becomes $\frac{82361}{\sqrt{L}}$. This formula only applies

to gas of the specific gravity ·420 under a pressure of half an inch head of water.

Putting D to represent any other diameter than 6 inches, we have the quantity discharged from such a pipe

$$= \frac{82361\ D^2}{36\sqrt{L}} = \frac{2288\ D^2}{\sqrt{L}}.$$

Putting g to represent the specific gravity of any other kind of gas, that of atmospheric air being 1, we have the quantity discharged of such a gas

$$= 2288\ D^2 \frac{\sqrt{\cdot 420\ H}}{\sqrt{\cdot 5\ Lg}} = 2288\ D^2 \sqrt{\cdot 84} \sqrt{\frac{H}{Lg}}$$

$$= 2096\ D^2 \sqrt{\frac{H}{Lg}} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Also putting Q for the quantity of gas discharged per hour in cubic feet, we have

$$D = \sqrt{\frac{Q}{2096\sqrt{\frac{H}{Lg}}}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Mr. Clegg* has given a long series of Tables, all calculated according to this formula, showing the quantities of gas of specific gravity ·420 delivered per hour from horizontal mains varying in length from 100 to 10,000 yards, and varying in diameter from 2 inches to 18 inches, under pressures varying from half an inch to 3 inches of water. There appears to be a general tendency to the belief that the actual quantities are much larger than those given in Mr. Clegg's Tables, or, which is the same thing, those which would result from the formula (4). For instance, in the recent important parliamentary inquiry into the case of the Great Central Gas Consumers' Company, their Engineer, Mr. Croll, estimated that with a pressure of 2½ inches a quantity equal to 173,000 cubic feet of gas would be delivered at the end of a 26-inch main 2¼ miles in length. Now if we calculate the quantity of gas which would

* The work by Mr. Clegg which is referred to here and at other places in this little volume is the one published by Mr. Weale in 1841.

be delivered from a main of this kind according to the basis of Mr. Clegg's Tables, we shall find it amount to less than half this quantity.

We have seen (equation 4) that a general expression in the form $x\mathrm{A} = \mathrm{Q}$ may be derived from any experiment, and that it is only necessary to determine the value of the coefficient x in this equation. The part A is always of course equal to $\mathrm{D}^2\sqrt{\frac{\mathrm{H}}{\mathrm{L}g}}$, so that the coefficient x is equal to

$$\frac{\mathrm{Q}}{\mathrm{D}^2\sqrt{\frac{\mathrm{H}}{\mathrm{L}g}}} = \frac{\mathrm{Q}\sqrt{\mathrm{L}g}}{\mathrm{D}^2\sqrt{\mathrm{H}}}.$$

We shall now determine the value of x according to this equation from several other experiments on coal gas.

Table showing the quantities of gas discharged from a pipe $\frac{62}{100}$ of an inch in diameter, in the experiments of M. Girard at the Hospital of St. Louis. In these experiments the density of the gas or the value of g *was* ·559, *and the pressure or value of* H *was* 1·34 *inches.*

Length of pipe, in yards.	Quantity discharged per hour, in cubic feet.	Value of x calculated from the equation $x = \frac{\mathrm{Q}\sqrt{\mathrm{L}g}}{\mathrm{D}^2\sqrt{\mathrm{H}}}$
41	99	1065
62	83	1096
93	74	1198
119	57	1045
138	53	1047
		5) 5451
The coefficient according to these experiments . .		1090

It will be observed that the value of x calculated from these experiments varies from 1045 to 1198, being a difference between the extremes equal to 14 per cent. The fairest way to adjust this variation in the experiments is, therefore, to take the mean and to assume the coefficient established by M. Girard at 1090.

The next experiments which we shall examine comprise a series of six given by Mr. Clegg in his work on Gas-Lighting.

Table showing the quantity of gas of specific gravity ·420 discharged per hour, according to Mr. Clegg's experiments, from a 6-inch main with a pressure equal to half an inch of water.

Length of pipe, in yards.	Quantity discharged per hour, in cubic feet.	Value of x calculated from the equation $x = \frac{Q\sqrt{g}}{D^2\sqrt{H}}$
3·46	44280	2100
4·5	38838	2100
7·5	30000	2096
16·5	20270	2099
25·	16460	2099
34·2	14080	2100
		6) 12594
The coefficient derived from Mr. Clegg's experiments on a 6-inch main		2099

Mr. Clegg gives a single experiment with a 4-inch main, in which he found that with a pressure equal to 3 inches, 852 cubic feet of gas of specific gravity ·398 were delivered from a main 10560 yards in length. The coefficient derived from this experiment is

$$\frac{852 \times \sqrt{10560 \times \cdot 398}}{16 \times \sqrt{3}} = 1993.$$

Most of the following experiments are taken from a Paper by Mr. Pole. In the last column the value of the coefficient x has been calculated as before, and in order to present a clear view of the way in which this coefficient varies with the diameter of the main, the results of the previous experiments are repeated in the Table.

No.	Diameter of pipe, in inches.	Length of pipe, in yards.	Pressure, in inches of water.	Specific gravity of gas, air being 1.	Quantity discharged in cubic feet per hour.	Value of x calculated from equation $x = \frac{Q \sqrt{Lg}}{D \sqrt{H}}$
1	0·5	10	1·25	·4	120	860
2	0·5	59	1·25	·4	60	1043
3	0·62	41	1·34	·559	99	1065
4	0·62	62	1·34	·559	83	1096
5	0·62	93	1·34	·559	74	1198
6	0·62	119	1·34	·559	57	1045
7	0·62	138	1·34	·559	53	1047
8	2·00	25	0·5	·528	1630	2094
9	4·00	10560	3·0	·398	852	1993
10	6·00	3·46	0·5	·42	44280	2100
11	6·00	4·5	0·5	·42	38838	2100
12	6·00	7·5	0·5	·42	30000	2096
13	6·00	16·5	0·5	·42	20270	2099
14	6·00	25·	0·5	·42	16460	2099
15	6·00	34·2	0·5	·42	14080	2100
16	8·00	1842	0·7	·4	6000	3042
17	10·00	100	3·00	·4	120000	4382
18	10·00	1760	3·00	·4	30000	4596
19	18·00	1760	1·00	·4	66000	5405
20	26·00	3130	·8	·42	103000	6173
21	26·00	4300	2·25	·42	175000	6990
22	26·00	4300	0·475	·42	80000	7255

Returning now to formula (4), according to which Mr. Clegg's Tables are calculated, on the supposition that x is equal to 2096, we shall find on examining the above Table, that this coefficient will not correspond with any of the experiments made on pipes of less diameter than 2 inches or greater than 6 inches. For instance, the formula used by Mr. Clegg would give more than double the true quantity delivered when applied to a pipe half an inch in diameter, and when applied to a main of 26 inches would give a result less than one-third of the true discharge from this main. To make this more clear, let us suppose it be required to calculate the delivery of gas according to the experiments above cited. For a half-inch pipe we have two experiments, one of which gives a coefficient of 860 and the other 1043, the mean of which is 952. Mr. Clegg's coefficient we have already seen is 2096, and the

coefficients derived from experiments on a 26-inch main are 6173, 6990, and 7255, the mean of which is 6806. Hence if we were to establish a rule for finding the quantity of gas delivered,

According to experiments on the ½-inch pipe, the formula would be

$$952\ D^2 \sqrt{\frac{H}{L\,g}}$$

According to Mr. Clegg's experiments, it would be

$$2096\ D^2 \sqrt{\frac{H}{L\,g}}$$

According to experiments on the 26-inch main, it would be

$$6806\ D^2 \sqrt{\frac{H}{L\,g}}$$

In examining these apparently irreconcileable results, the principal feature which immediately strikes us is, that the friction of the gas in passing through the pipes is not represented or taken into account in any of the formulæ. Now it appears that comparing the two coefficients 952 and 6806, one of which is seven times greater than the other, that a 26-inch pipe will deliver seven times the quantity due to its area as compared with a half-inch pipe. This is very nearly in the proportion of the square roots of the diameters, for

$$952 : 6806 :: \sqrt{\cdot 5} : 5{\cdot}055$$

The root of 26 being 5·099, this ought to be the fourth term in the above proportion, but considering all the circumstances of the case the correspondence is tolerably near.

It would be wearisome to go through a similar comparison with all the other experiments. It may suffice to say, that no other form of expression agrees so well with the experiments as that in which the quantities delivered are further increased as the square roots of the diameters.

I therefore propose a formula in which the square root of the diameter shall be used as a multiplier, and will add a Table showing the results of all the preceding experiments when compared with quantities calculated in this way.

It will be advisable to take the experiments on the 26-inch main as the most trustworthy; and here, as we are going to introduce a new multiplier equal to 5·099, the square root of the diameter, we must of course divide the coefficient 6806 by 5·099, in order to find the new coefficient.

Hence $\frac{6806}{5{\cdot}099} = 1335$, the new coefficient required. The general formula then which I shall propose for calculating the quantities of gas delivered through pipes, in the present state of our knowledge, is

$$1335\ D^2 \sqrt{\frac{H\,D}{L\,g}} \quad . \quad . \quad . \quad . \quad (6)$$

Table showing the quantities of gas delivered by experiment and theory in the following series of experiments, which are numbered to correspond with those in the Table at page 272.

No.	Quantity by experiment.	Quantity by calculation.	No.	Quantity by experiment.	Quantity by calculation.
1	120	132	12	30000	46862
2	60	54	13	20270	31527
3	99	97	14	16460	25424
4	83	80	15	14080	22011
5	74	65	16	6000	7433
6	57	57	17	120000	115611
7	53	53	18	30000	27554
8	1630	1481	19	66000	69206
9	852	1130	20	103000	113710
10	44280	68726	21	175000	162443
11	38838	60556	22	80000	74453

In this comparison of theoretical quantities with actual discharges it will be seen that considerable differences exist.

With the exception of experiments 9 to 15, however, the differences are perhaps not more than might be expected when the numerous disturbing causes are taken into account. In the first place, the mains may not have been strictly horizontal, although assumed to have been so by the authors of the experiments. Secondly, there may have been bends or angles in the course of the main, as in the case of experiment No. 9, which is recorded in Mr. Clegg's Treatise on Gas-Lighting, and was made on a pipe nearly six miles in length, the discharging extremity being brought round in a large circle nearly to the place where the gas first entered the pipe. In this experiment it will be observed the theoretical quantity is more than 30 per cent. in excess of the actual discharge.

By far the greatest variation, however, is found in Mr. Clegg's experiments on 6-inch pipes (experiment 10 to 15), where the results by theory are about 50 per cent. more than by experiment. I am unable to account for this variation, which does not exist to anything like the same extent in any of the other experiments.

The extreme shortness of the lengths of main employed by Mr. Clegg may have exercised some influence by admitting atmospheric air to resist the flow of the gas.

For those, however, who are disposed to place confidence in Mr. Clegg's experiments, to the exclusion of others, it will be readily competent to derive a coefficient from Mr. Clegg's experiments by dividing the number in the last column of Table at page 272 by 2·449, the square root of 6.

The tabular number in Mr. Clegg's experiments being 2099, we have $\frac{2099}{2 \cdot 449} = 857$, the coefficient to be used according to Mr. Clegg's experiments.

The conclusion to be drawn from a review of all the experiments which have been made on the flow of gas through horizontal pipes is this, that taking friction and everything else into consideration, the quantity is equal to x A, where

$$A = D^2 \sqrt{\frac{H D}{L g}},$$

and where x is the coefficient to be determined by experiment.

Let Q be the quantity determined by experiment, then we have

$$x = \frac{Q\sqrt{Lg}}{D^2\sqrt{DH}}$$

Those who desire a more exact method of determining the quantities of gas which will be discharged through pipes of various diameters must be content to wait for the determination of x by means of an extensive and accurate series of experiments, which by giving the quantity of gas having a known density discharged through mains of certain length and diameter under a known pressure, will afford the means of calculating the value of x, or the coefficient to be used in all other determinations.

I think it right to remark, that in Mr. Pole's very admirable Paper,* from which I have quoted some of the preceding experiments, the author arrives by an entirely different method at a formula very nearly identical with that which I have given.

The formula which Mr. Pole proposes for gas is

$$1350\ D^2\sqrt{\frac{HD}{Lg}},$$

the only difference being that his coefficient is 1350 instead of 1335. Mr. Pole adds in a note, that in some recent experiments on a 9-inch main giving the discharge under various pressures, the results would require his coefficient to be reduced to 1150; but goes on to say that it would not be judicious to adopt such an alteration for general use unless confirmed by other experiments on pipes of different diameters.

While these sheets are going through the press a very extensive series of Tables is being published in the 'Journal of Gas-Lighting,' showing the discharge of gas under various pressures from $\frac{1}{10}$th of an inch up to $2\frac{1}{2}$ inches, and from

* Published in the 'Journal of Gas-Lighting' for June 1852.

mains of all diameters up to 30 inches. The quantities in these Tables agree remarkably well with those calculated by formula (6).

We now come to the third division of the subject, namely, where mains are laid with an inclination above or below the point of supply. We have here again to regret the insufficiency, or rather the entire absence, of such experiments as would elucidate the inquiry. The rule which appears to be generally adopted is this, that every variation in the inclination of the main causes a corresponding difference of pressure at the rate of one hundredth of an inch for every foot of rise or fall. Thus when a main rises 10 feet above a datum line at which the pressure is known, an increase of pressure is obtained equal to one-tenth of an inch, and on the other hand when a main is at any point 10 feet below such a datum line, the pressure is diminished to the extent of one-tenth of an inch.

ON THE LOSS OF PRESSURE CAUSED BY PASSING GAS THROUGH MAINS.

Whatever be the initial pressure with which the gas leaves the gas-holder and enters the main, it gradually loses a portion of this initial pressure, and at the end of a long main no longer possesses the force which it did at the beginning. It is often very important to be able to determine this loss of pressure, especially when works are situated a considerable distance from the district to be lighted, as in the case of the Great Central Company's Works and also those of the Western Gas Company at Kensall Green.

On this subject very little is known, and very few experiments have been made in this country.

M. D'Hurcourt, however, the author of a recent Treatise on Gas-Lighting, which has been before referred to, gives the following rule for ascertaining the loss of pressure sustained by passing a given volume of gas through a main.

"Take the square of the quantity of gas, expressed in *litres*, which passes in one second through any point in the main; multiply the square by the length of the main in *metres*, and divide the product by the 5th power of the diameter of the main expressed in *centimetres*. This quotient multiplied by the number 2·7 will represent the loss of pressure expressed in *centimetres*."

Now, to reduce this rule to a convenient form in English measures, put

Q = the quantity of gas in thousands of cubic feet which are required to be passed through the main per hour.

L = length of main in yards.

D = diameter in inches.

Then the loss of pressure in inches of water at the end of the main, according to M. D'Hurcourt's rule, will be

$$\frac{L\,Q^2}{D^5} \times \cdot 611.$$

In his evidence before the Committee on the Great Central Gas Consumers' Bill, Mr. Croll proposed to convey 173,000 cubic feet of gas per hour through a 26-inch main, 2¼ miles in length, and his calculation was, that at the end of the main the pressure would be diminished 2½ or 3 inches. But if we calculate the loss of pressure by M. D'Hurcourt's rule, we shall find it amount to more than 5 inches, or more than the pressure of Mr. Croll's gas-holders at the works. Thus

$$\left.\begin{array}{l} Q = 173 \\ L = 3960 \\ D = 26 \end{array}\right\} \text{Then } \frac{173^2 \times 3960}{26^5} = 9 \cdot 13,$$

and $9 \cdot 13 \times \cdot 611 = 5 \cdot 58$ inches loss of pressure.

It follows therefore that either Mr. Croll or the French author must be very much in error.

CHAPTER XVIII.

EXPERIMENTS ON COAL GAS.—MODES OF TESTING AND COMPARING GAS.

In the analysis of gases a high degree of chemical knowledge is essential, and this subject forms in itself a very important branch of chemical investigation. Into this we do not propose to enter, but shall merely notice a few of those simple operations which the manager of every establishment for the manufacture of gas should readily be able to perform, in order to satisfy himself and others of the value of his gas and to afford the means of rectifying errors.

It is a lamentable fact that, notwithstanding the progress which the science of gas-lighting has made of late years and the amount of practical chemical skill which has been applied to the subject, there are yet many towns in England where the gas is so bad and so imperfectly purified as to be quite unfit for consumption in private houses, and where people are afraid to introduce it, well knowing its injurious effect on many articles of value exposed to its influence.

The chief operations which will claim attention in a practical point of view are those of testing the purity of gas, to ascertain its freedom or otherwise from sulphuretted hydrogen, ammonia, and carbonic acid gas; the process of weighing gas to ascertain its specific gravity; and, thirdly, the process of testing by various agents to determine the proportion of olefiant gas and light-giving hydrocarbons which the gas contains. There is a further mode of comparing gases by means of photometers, or instruments contrived for the purpose of measuring light.

Tests for Sulphuretted Hydrogen, Ammonia, and Carbonic Acid Gas.

Test papers for detecting sulphuretted hydrogen are prepared by moistening common writing-paper with a solution of

acetate of lead or nitrate of silver, the latter being the most delicate test. The presence of this impurity may also be detected by passing the gas through either of these solutions. Another method, sometimes practised, is to pass the gas into pure distilled water, then to add a single drop either of the acetate of lead, the nitrate of silver, or the chloride of bismuth: if any sulphuretted hydrogen be present, it will immediately show itself by blackening the water. When water is impregnated with gas containing sulphuretted hydrogen, it may even be detected by the fœtid and disagreeable odour resembling that of rotten eggs.

Test for Ammonia.

This being an alkali, the test papers to be used must be either yellow turmeric paper or litmus paper first reddened by vinegar or any other weak acid. If the original blue colour of the litmus paper be restored, or the yellow colour of the turmeric be turned to a brown, it is a sign of the presence of ammonia; but if the reddened paper be unaffected, then the gas is not alkaline in its character, and will probably itself redden the unchanged litmus paper, in which case the gas is acid.

Test for Carbonic Acid Gas.

Paper steeped in the blue tincture of litmus is rendered red both by carbonic acid gas and by sulphuretted hydrogen. In order to distinguish accurately which of these impurities is present, a solution may be made of pure barytes in the tincture of litmus. If the gas be passed into this solution, no change will be produced if only sulphuretted hydrogen be present, but if carbonic acid gas be present, a precipitate of the carbonate of barytes will immediately fall down. Carbonic acid gas may also be detected by adding to water impregnated with the gas a few drops of sulphuric acid, when minute air-bubbles of carbonic acid gas will be rapidly disengaged.

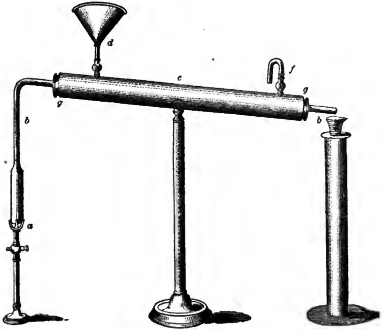
A very useful little instrument is made by Mr. Wright, of

Westminster, for the purpose of detecting sulphuret of carbon in gas. The presence of this compound of sulphur had long been suspected, and, as it cannot be detected by the ordinary test papers which are used for sulphuretted hydrogen, has often escaped observation. Every combination of sulphuric acid, however, being highly injurious in coal gas, it is important that every possible pains should be taken to remove this impurity. Mr. Wright's apparatus is equally useful for detecting sulphuretted hydrogen or any other compound of sulphuric acid.

The arrangement consists of a simple apparatus for condensing the products of combustion from an ordinary gas flame, and of applying to the liquid so condensed a salt of barytes, which immediately precipitates the sulphur, when present in ever so small a quantity.

a, in fig. 70, is an argand or other gas burner fitted with a

Fig. 70.



chimney which is gradually contracted into a small tube, *b b*, half an inch in diameter, which tube is bent and carried through a metal cylinder *c*, about 18 inches long and 2 inches diameter. This cylinder is kept full of water, which is retained by means of a screwed cap, *g g*, at each end, the cap being provided with a small India-rubber washer, which makes a perfect joint at each end of the tube. *d* is a funnel for filling the tube with water, and *f* is a siphon by which the water overflows when the tube is full. The vapours which escape from the combustion of the gas at *a* pass through the tube *b*, from which the condensible part drops in the state of fluid into a glass placed to receive it, while the carbonic acid escapes at the same open end of the tube. The water which drops from the tube is generally colourless, nearly tasteless, but with a peculiar and not unpleasant odour.

When a drop of either the nitrate of baryta or the chloride of barium is added to the water thus condensed from the combustion of ordinary gas, a flocculent white powder immediately discolours the water, but on testing the condensed liquid from cannel coal gas at the Western Gas-Works, where Mr. Wright has paid great attention to the purification, there are only very slight indications of any precipitate by either of these salts. This is considered by competent authorities the very severest test to which gas can be subjected,—these solutions detecting sulphuric acid in all soluble states of combination.

On the Weighing of Gas.

The most accurate method of weighing gas is to exhaust a globe of known capacity, such as are now sold by philosophical instrument makers, fitted with a cap and stop-cock for the purpose. The globe being accurately weighed when exhausted and when filled with gas, the weight of the gas, of course, will be the difference between the two weights. Whatever be the capacity of the globe, the weight of 100 cubic inches of the gas can be readily calculated when the weight of its contents are known.

Then as 100 cubic inches of air of mean temperature and pressure weigh 31·017 grains, say as 31·017 is to the weight of 100 cubic inches of the gas, so is unity or the specific gravity of air to the specific gravity of the gas. Or another method may be adopted, which is independent of the capacity of the globe and does not require this capacity to be determined at all. Weigh the globe when filled with gas, also when filled with air, and when exhausted; from these three separate weights, that of the air contained in the globe may be ascertained as well as that of the gas which it contains. Then the weight of the gas divided by that of the air is equal to the specific gravity. In performing the operation of weighing gases, however, many precautions are necessary, and many niceties of manipulation must be practised, which can only be successfully carried out by an accomplished chemist.

For instance, the gas must be reduced to mean pressure and temperature, and corrections must also be made for moisture both in the gas and the air, unless the gas has been previously dried, which is now the practice of the best chemists.

The corrections for pressure and temperature are very simple. Suppose a given volume, say 100 cubic inches of gas, to be standing in a gas-holder or in any graduated vessel ready for examination, let the height of the mercury in the barometer be 29·4 inches, and let it be required to determine the volume which the gas will occupy when the pressure of the atmosphere is equal to 30 inches of mercury. It is evident here that the volume of the gas will be decreased, and the amount of decrease has been found to be inversely as the pressure. Hence 30 : 29·4 :: 100 : 98, the volume under a pressure of 30 inches of mercury.

The correction for temperature is made so as to reduce the volume of gas to that which it would occupy at 60° on Fahrenheit's scale, which in experiments is usually taken as the mean temperature. It has been found by numerous investigations that the rate of expansion in gases is uniform for all degrees of heat, and the experiments of MM. Dulong and Petit, Rudburg,

Magnus, and Regnault have determined this expansion, as a mean of all their experiments, to be at the rate of one part in 460 for each degree of heat on Fahrenheit's scale. It follows from this law that 460 measures of gas at a temperature of 0° become $460 + t$ at any given temperature equal to t. Hence arises a very simple mode of ascertaining the volume for any given temperature, for let v be the volume occupied by the gas at a temperature t, then to find v' the volume occupied at any other temperature t' we have

$$460 + t : 460 + t' :: v : v', \text{ or}$$

$$v' = v \frac{460 + t'}{460 + t}.$$

For example, to find the volume which 100 cubic inches of gas at a temperature of 45° would occupy when the temperature rises to 60°.

$$\text{Here } v' = 100 \frac{460 + 60}{460 + 45} = 102{\cdot}97.$$

Correction for Moisture.

It has been ascertained by careful experiments that 100 cubic inches of permanent aqueous vapour corrected for a temperature of 60° and a mean pressure of 30 inches weigh 19·29 grains. If we then know the proportion of aqueous vapour absorbed by gas at different temperatures when standing over water or in contact with water, we shall have the means of determining from the known volume and weight of the moist gas the volume and weight of the dry gas. Professor Faraday, in his 'Chemical Manipulation,' gives the following Table, which is founded on the experiments of Dr. Dalton and Dr. Ure, and which ranges through most of the temperatures at which gas is likely to be weighed.

Table showing the proportion by volume of aqueous vapour existing in any gas standing over or in contact with water at the corresponding temperatures, and at a mean barometric pressure of 30 *inches.*

Temp.	Proportion of vapour in 1 volume of gas.	Temp.	Proportion of vapour in 1 volume of gas.
40°	·00933	61°	·01923
41	·00973	62	·01980
42	·01013	63	·02000
43	·01053	64	·02120
44	·01093	65	·02190
45	·01133	66	·02260
46	·01173	67	·02330
47	·01213	68	·02406
48	·01253	69	·02483
49	·01293	70	·02566
50	·01333	71	·02653
51	·01380	72	·02740
52	·01426	73	·02830
53	·01480	74	·02923
54	·01533	75	·03020
55	·01586	76	·03120
56	·01640	77	·03220
57	·01693	78	·03323
58	·01753	79	·03423
59	·01810	80	·03533
60	·01866		

It is easy from this Table to determine the quantity of aqueous vapour present in gas of any given temperature which is standing over water or which has been in contact with water; for it is only necessary to multiply the volume of the moist gas by the number corresponding to the temperature in order to find the volume of aqueous vapour which is present.

Suppose 120 cubic inches of moist gas at a temperature of 70° weighing 22 grains under mean barometric pressure, then the volume of vapour present is equal to $120 \times {\cdot}02566 = 3{\cdot}079$ cubic inches. This volume corrected to a temperature of 60°

will have to be deducted from the whole volume of gas corrected to the same temperature.

Now 120 cubic inches at 70° are equal to

$120 \times \frac{460+60}{460+70} = 117{\cdot}74$ cubic inches at a temperature of 60°. Hence $117{\cdot}74 - 3{\cdot}079 = 114{\cdot}66$ cubic inches, the volume of dry gas at mean temperature. Then to find the weight of this volume of dry gas we must deduct from the whole weight of 22 grains the weight of 3·079 cubic inches of aqueous vapour, which is equal to $3{\cdot}079 \times {\cdot}1929 = {\cdot}5939$ grains. Hence we have $22{\cdot} - {\cdot}5939 = 21{\cdot}4061$ grains as the weight of 114·66 cubic inches of dry gas. From this it follows by simple proportion that 100 cubic inches of the dry gas corrected for temperature and moisture will weigh

$$\frac{21{\cdot}4061 \times 100}{114{\cdot}66} = 18{\cdot}67 \text{ grains.}$$

Then as 100 cubic inches of air at mean temperature and pressure weigh 31 grains, the specific gravity of the gas will be

$$\frac{18{\cdot}67}{31} = {\cdot}602.$$

There are some advantages in operating on the moist gas, because the volume can be measured before passing it into the globe in which it is weighed; and in this case no error will be made even if the globe be not perfectly exhausted, or if the globe be not quite filled with gas, the only thing necessary being the increase of weight due to the gas actually admitted as measured by a graduated jar before transferring it to the globe. This measurement cannot so perfectly be made when the gas is dried beforehand, in which case the globe must be perfectly exhausted and perfectly filled with gas, when, its capacity being known, the specific gravity can be arrived at as before.

The simplest method of drying gas is to pass it through a tube filled with some substance having a powerful attraction for water. The tubes used are about half an inch in diameter and from 12 to 20 inches long. Chloride of lime will answer

well as a desiccating material for gas which does not contain much ammonia. The chloride of lime should be heated and fused in an earthenware crucible, a temperature below that of visible redness being quite sufficient for the purpose; then poured upon a clean metallic or stone surface, and, as soon as it has solidified, broken up and put into stopped bottles. This chloride being divided into a mixture of large and small fragments is to be introduced rapidly into the tube, until the latter is nearly full; the apparatus is then ready for use. The tube may be connected with the jar, gas-holder, or other vessel containing or evolving the gas by caoutchouc connectors, or in any other convenient way; and so much gas should be passed through it as effectually to expel all the common air before the globe or vessel to be filled with the dry gas be attached. That being done, the gas should be allowed to pass slowly, 100 cubical inches having from 10 to 20 minutes allowed for their passage through such a tube as that described, though if the period be lengthened no injury is occasioned. If the tube be of smaller diameter, more time should be proportionably allowed.

Instead of the chloride of lime, fused potash or fused carbonate of potash may be employed, but it is to be remembered that ordinary potassa fusa generally evolves a little oxygen during its solution, and hence may occasionally be exceptionable. Chloride of lime will not answer for ammonia, or for sulphurous and some other acid gases. Potash, or carbonate of potash, answers perfectly well for ammonia, but not for acid gases. Sulphuric acid is a very excellent desiccator for many gases, and may be used in a tube by first curving the tube, then filling it with fragments of glass or rock crystal, and afterwards pouring in so much concentrated oil of vitriol as shall moisten the fragments but not cause obstruction to the passage of the gas. By moving the tube a little from time to time the acid is made to pass from place to place, it becomes mixed, and it re-moistens the fragments, which from the previous quiescent state of the apparatus may have drained con-

siderably. This substance is effectual with almost all ordinary gases except ammonia.*

Mr. Wright has contrived an ingenious apparatus for taking the specific gravity of gas by means of a balloon containing, when full of gas, 1000 cubic inches, and capable of being gauged by a ring which fits its largest diameter when the balloon is full. The following are Mr. Wright's directions for performing the experiment, with the Table which he has compiled for correcting the temperature and pressure of the gas according to the standard generally made use of,—namely, a temperature of 60° Fahrenheit and a barometric pressure of 30 inches of mercury.

Expel the air from the balloon by folding in the form in which it is first received, ascertain the weight of the balloon and car, fill the balloon with gas, insert the stopper, and put as many grains† in the car as will balance it in the air; add the number of grains which it carries to the weight of the balloon, and deduct the amount from the tabular number corresponding to the degree of temperature indicated by the thermometer, and the pressure indicated by the barometer; divide the result by the tabular number due to the temperature and pressure of the gas, to ascertain which allow the gas to blow upon the bulb of the thermometer until the mercury is stationary, and the three first figures are the specific gravity.

Example 1.

Temperature of the air, 70° Barometer . . 28·5 in.	Tabular number 932.
Temperature of gas . 56° Barometer always the same as air . 28·5 in.	Tabular number 958.

* Faraday's 'Chemical Manipulation,' p. 390.

† The weights used are not troy grains, 100 of them being equal to 30·5 troy grains: they are each equal to a cubic inch of air, when the barometer is at 30 inches, and the thermometer at 60 degrees.

Weight of balloon and grains in car, 560.

```
                                     932 Tabular number for the air.
                                     560 Weight of balloon, &c.
                                    ----
Tabular number for the gas    958) 3720 (388 Specific gravity.
                                   2874
                                   ----
                                    8460
                                    7664
                                    ----
                                     7960
                                     7664
                                     ----
                                      296
```

EXAMPLE 2.

Temperature of the air, 40° Barometer . . 30·5 in.	Tabular number 1058.
Temperature of gas . 62° Barometer always the same as air . 30·5 in.	Tabular number 1013.

Weight of balloon and grains in car, 560.

```
                                     1058 Tabular number for the air.
                                      560 Weight of balloon, &c.
                                     ----
Tabular number for the gas    1013) 4980 (491 Specific gravity.
                                    4052
                                    ----
                                     9280
                                     9117
                                     ----
                                      1630
                                      1013
                                      ----
                                       617
```

NOTE.—This Table will also be found convenient for correcting the quantity of gas made, as indicated by the station meter; the quantity being divided by the tabular number due to the temperature and pressure, will give the amount, as if the gas had been at 60° Fahrenheit and 30° barometer.

Bar.	THER. 32°	34°	36°	38°	40°	42°	44°	46°	48°	50°
28·0	988	984	980	976	971	968	964	960	956	952
28·1	991	987	983	979	975	971	967	963	959	955
28·2	995	991	987	983	979	975	971	967	963	959
28·3	998	994	990	986	982	978	974	970	966	962
28·4	1002	998	993	990	985	981	977	973	970	966
28·5	1005	1001	997	993	989	985	981	977	973	969
28·6	1009	1005	1000	996	992	988	984	980	976	972
28·7	1012	1008	1004	1000	996	992	988	984	980	976
28·8	1016	1012	1008	1003	999	995	991	987	983	979
28·9	1020	1015	1011	1007	1003	999	995	991	987	983
29·0	1023	1019	1015	1010	1006	1002	998	994	990	986
29·1	1027	1022	1018	1014	1010	1006	1002	998	993	989
29·2	1030	1026	1022	1017	1013	1009	1005	1001	997	993
29·3	1034	1029	1025	1021	1017	1012	1008	1004	1000	996
29·4	1037	1033	1029	1024	1020	1016	1012	1008	1004	1000
29·5	1041	1036	1032	1028	1024	1019	1015	1011	1007	1003
29·6	1044	1040	1036	1031	1027	1023	1019	1015	1010	1006
29·7	1048	1043	1039	1035	1031	1026	1022	1018	1014	1010
29·8	1051	1047	1043	1038	1034	1030	1026	1022	1017	1013
29·9	1055	1050	1046	1042	1038	1033	1029	1025	1021	1017
30·0	1058	1054	1050	1045	1041	1037	1033	1028	1024	1020
30·1	1062	1057	1053	1049	1044	1040	1036	1032	1028	1023
30·2	1065	1061	1057	1052	1048	1044	1039	1035	1031	1027
30·3	1069	1064	1060	1056	1051	1047	1043	1039	1034	1030
30·4	1072	1068	1064	1059	1055	1051	1046	1042	1038	1034
30·5	1076	1071	1067	1063	1058	1054	1050	1045	1041	1037
30·6	1079	1075	1071	1066	1062	1057	1053	1049	1045	1040
30·7	1083	1079	1074	1070	1065	1061	1057	1052	1048	1044
30·8	1087	1082	1078	1073	1069	1064	1060	1056	1051	1047
30·9	1090	1086	1081	1077	1072	1068	1063	1059	1055	1051
31·0	1094	1089	1085	1080	1076	1071	1067	1063	1058	1054

Bar.	THER. 52°	54°	56°	58°	60°	62°	64°	66°	68°	70°
28·0	948	944	941	937	933	930	926	922	919	915
28·1	952	948	944	940	937	933	929	926	922	919
28·2	955	951	947	944	940	936	933	929	925	922
28·3	958	955	951	947	943	940	936	932	929	925
28·4	962	958	954	950	947	943	939	936	932	928
28·5	965	961	958	954	950	946	943	939	935	932
28·6	969	965	961	957	953	950	946	942	939	935
28·7	972	968	964	960	957	953	949	945	942	938
28·8	975	971	968	964	960	956	952	949	945	941
28·9	979	975	971	967	963	960	956	952	948	944
29·0	982	978	974	970	967	963	959	955	952	948
29·1	985	982	978	974	970	966	962	959	955	951
29·2	989	985	981	977	973	969	966	962	958	954
29·3	992	988	984	981	977	973	969	965	961	957
29·4	996	992	988	984	980	976	972	969	965	961
29·5	999	995	991	987	983	979	976	972	968	964
29·6	1002	998	994	991	987	983	979	975	971	968
29·7	1006	1002	998	994	990	986	982	978	975	971
29·8	1009	1005	1001	997	993	989	986	982	978	974
29·9	1013	1009	1005	1001	997	993	989	985	981	978
30·0	1016	1012	1008	1004	1000	996	992	988	984	981
30·1	1019	1015	1011	1007	1003	999	995	992	988	984
30·2	1023	1019	1015	1011	1007	1003	999	995	991	987
30·3	1026	1022	1018	1014	1010	1006	1002	998	994	990
30·4	1029	1025	1021	1017	1013	1009	1005	1002	998	994
30·5	1033	1029	1025	1021	1017	1013	1009	1005	1001	997
30·6	1036	1032	1028	1024	1020	1016	1012	1008	1004	1000
30·7	1040	1036	1031	1027	1023	1019	1015	1011	1007	1004
30·8	1043	1039	1035	1031	1027	1023	1019	1015	1011	1007
30·9	1046	1043	1038	1034	1030	1026	1022	1018	1014	1010
31·0	1050	1046	1042	1037	1033	1029	1025	1021	1017	1013

Bar.	THER. 72°	74°	76°	78°	80°	82°	84°	86°	88°	90°
28·0	912	908	905	901	898	895	891	888	885	881
28·1	915	912	908	905	901	898	894	891	888	884
28·2	918	915	911	908	904	901	898	894	891	888
28·3	922	918	914	911	908	904	901	897	894	891
28·4	925	921	918	914	911	907	904	900	897	894
28·5	928	925	921	917	914	910	907	904	900	897
28·6	931	928	924	921	917	914	910	907	903	900
28·7	935	931	927	924	920	917	913	910	907	903
28·8	938	934	931	927	924	920	917	913	910	906
28·9	941	937	934	930	927	923	920	916	913	910
29·0	944	941	937	934	930	926	923	919	916	913
29·1	948	944	940	937	933	930	926	923	919	916
29·2	951	947	944	940	936	933	929	926	922	919
29·3	954	950	947	943	940	936	933	929	926	922
29·4	957	954	950	946	943	939	936	932	929	925
29·5	961	957	953	950	946	942	939	935	932	928
29·6	964	960	957	953	949	946	942	939	935	932
29·7	967	963	960	956	952	949	945	942	938	935
29·8	970	967	963	959	956	952	948	945	941	938
29·9	974	970	966	963	959	955	952	948	944	941
30·0	977	973	969	966	962	958	955	951	948	944
30·1	980	976	973	969	965	962	958	954	951	947
30·2	983	980	976	972	969	965	961	958	954	950
30·3	987	983	979	975	972	968	964	961	957	954
30·4	990	986	982	979	975	971	968	964	960	957
30·5	993	989	986	982	978	974	971	967	963	960
30·6	996	993	989	985	981	978	974	970	967	963
30·7	1000	996	992	988	985	981	977	973	970	966
30·8	1003	999	995	991	988	984	980	977	973	970
30·9	1006	1002	998	995	991	987	984	980	976	973
31·0	1009	1006	1002	998	994	990	987	983	979	976

The preceding Table of course contains no correction for moisture, nor is this commonly considered necessary in practice if the experiments are made in a dry room at some distance from the gas-holder or vessel in which the gas has been standing over water.

The correction applied for barometric pressure is precisely the same as that explained at page 283, namely, a correction in the inverse ratio of the pressure. The correction for temperature is not quite the same as explained at page 284, since Mr. Wright has assumed a different rate of expansion according to the increase of temperature. The correction made by means of this Table will, however, probably be found sufficiently accurate for all practical purposes.

This Table is a simple calculation of the space which will be occupied by a thousand volumes either of gas or air, when reduced from the temperature and pressure of the Table to the standard temperature of 60° Fahrenheit and 30 inches pressure. Thus a thousand volumes of gas at temperature 50° and pressure 28·5 will occupy at standard pressure and temperature 969 volumes.

Referring to what has already been said with respect to correction for temperature and pressure, a very simple expression may be derived for converting any quantity of gas—say a thousand volumes—into the space which it would occupy at the standard temperature and pressure. Putting t and p respectively for the observed temperature and pressure of gas or air, we have

$\frac{1000 \times \overline{460+60}}{460+t}$ = the volume corrected for pressure, and

$\frac{1000 \times \overline{460+60}}{460+t} \times \frac{p}{30}$ = the volume corrected for both pressure and temperature: now this latter expression, when reduced, is equal to $\frac{17333{\cdot}3\ p}{460+t}$. Mr. Wright, in calculating his Table, seems to have assumed the expansion at $\frac{1}{448}$th of the whole volume, for each degree of heat; so that the for-

mula by which he has calculated his Table would be $\frac{16933 \cdot 3}{448 + t} p$. This will give tabular numbers differing very slightly from those given by my formula,—which I prefer, however, because an expansion of 1 in 460 appears to agree better than any other with the mean of the best experiments on the subject.

ON THE BROMINE TEST.

The method of ascertaining the amount of condensation produced in coal gas by the addition of a single drop of bromine, is now much preferred to the use of chlorine, which presented some difficulties in estimating the volumes to be mixed.

The chlorine test, however, is a very beautiful experiment in the hands of a skilful operator. It requires one measure of chlorine gas to be passed into a jar inverted over water, and containing two measures of coal gas. This mixture will cause a diminution of volume in the gas, and an oily liquid will be formed by the olefiant gas uniting with the chlorine. The chlorine ought to be in excess; and the remaining portion having been removed by the addition of a few drops of a strong solution of potash, the diminution of volume which the coal gas has sustained will be a measure of its value, by indicating the proportion of olefiant gas contained in it.

For the purpose of testing gas with bromine a glass tube is used about 3 feet long and half an inch diameter inside. The tube is closed at one end and is bent at the other into a small semicircle, so that the straight part of the tube is about 33 inches long, the remaining 3 inches being occupied by the bend. The straight part of the tube is graduated into hundredths towards the closed end as far as 25 divisions, or one-fourth of the length; this graduation serving to show the diminution in the volume of the gas effected by the bromine.

The tube is to be filled with water and the curved or open end placed over an orifice from which the gas is allowed to

flow. After passing up through the water the gas begins to displace the latter, and must be allowed to do so till the gas exactly fills the tube from the zero division or the beginning of the graduation to the top of the tube. The curved end of the tube remains filled with water, which acts as a seal and prevents the escape of gas. It is usual now to add a few drops of a solution of potash to remove any carbonic acid which may be in the gas. A portion of bromine about the size of a small pea is then to be dropped into the open end of the tube, and the thumb being placed firmly on this open end, the tube is to be inverted once or twice so as to bring the bromine into perfect contact with the gas. After two or three inversions of the tube the thumb may be withdrawn under water, and a few drops of a solution of potash added, in order to remove from the tube the vapour of bromine contained in it. To effect this removal the thumb is to be again pressed on the open end of the tube, and its contents agitated by again inverting the tube once or twice. The open end of the tube is then to be placed in water, which will now rise considerably above zero, and after remaining at rest for some time, the height of the water may be read off on the graduated part of the tube. The division so read off will of course represent the condensation of the gas in parts of 100.

Some of the inferior gases are not condensed by bromine to the extent of more than 4 or 5 per cent., while some of the rich and highly illuminating cannel coal gases are condensed as much as 12 and 14 per cent.

ON THE COMPARISON OF GASES BY MEANS OF THE PHOTOMETER.

The method of estimating the illuminating power of gases in measures of which the unit is a single wax candle consuming a known weight of wax per hour, is a test of great beauty and simplicity. By many of the most experienced gas engineers this test of the value of a gas is preferred to all other methods

of comparison. It has been justly said that the specific gravity of a gas is not alone a test of value, because this may be due to the presence of carbonic acid. But when the actual lighting power is tried by the photometer, if the standard should fall short of that which might be expected from the specific gravity of the gas, then the presence of carbonic acid may be fairly suspected.

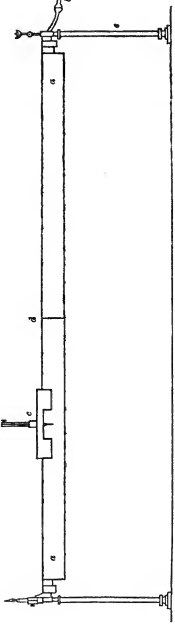
The earliest method of comparing the lighting power of gas with that of candles or any other standard was that proposed by Count Rumford, and commonly known as the method of shadows. For this purpose a simple apparatus was designed, and named after its inventor, the Rumford photometer. This consisted simply of a black box in which a white space was painted to receive the shadows made by intercepting the light from a gas-burner and a candle placed at such distances as to give shadows of precisely the same intensity. When the distances are so adjusted that the shadows are precisely similar, then the lighting powers of the two bodies are proportionate to the squares of their distances from the surface which intercepts the light. Thus if a gas-burner give a shadow equal to that of a candle placed at one-third of the distance, the gas is said to be equal to nine candles: if it gives a shadow equal to that of a candle placed at one-fourth of the distance, it is equal to sixteen candles, and so on. In general terms, let d be the distance from the candle to the intercepting surface, and δ the distance from the gas-burner to the same on a similar surface, then when the shadows are equal, the illuminating power of the gas is equal to $\frac{\delta^2}{d^2}$, that of the candle being unity. Hence if the distance of the candle be a fixed distance equal to 10 inches, it will only be necessary to cut off two figures from the square of the gas-burner's distance to find the number of candles to which the gas is equal. Suppose the distance of the gas-burner to be 24 inches, while that of the candle is 10 inches, then $24^2 = 576$, and the light given by the gas is equal to 5·76 candles.

Although the method of comparison by shadows is still highly spoken of by some who have practised it for many years, and have acquired a habit of great accuracy in discriminating the depth of shadows, it is not in general use at the present time, the Rumford photometer having been superseded by an instrument invented by Professor Bunsen, of Marburg, and first introduced in this country by Dr. Lyon Playfair, who described it to Mr. King, of Liverpool. The comparison made by the Bunsen photometer is not one of shadows, but is a comparison of transmitted light passing through a transparent surface, with reflected light striking on an opaque surface. This comparison is made by interposing between two lights a disk of paper with an annular space made transparent, and surrounding a small part in the centre which is opaque. Now, if any light whatever be placed behind a disk of this kind, the transparent ring will be illuminated, while a dark circle will appear in the centre. If another light be now placed in front of the paper at such a distance as to cause the reflection from the opaque circle to be greater than that transmitted through the transparent ring, the centre space will be more illuminated than the ring. Again, if the light in front be placed at such a distance that the reflection is less than the transmitted light, then the central spot will appear darker than the ring, and be distinctly visible. When, however, the light is so placed that the light reflected and that transmitted are exactly equal, then the centre spot is invisible, as the whole surface of the paper appears alike, and no difference is observed between the central spot and the annular space which surrounds it. When this condition obtains, the lights are to each other as before, in the ratio of the squares of their distance from the disk.

Photometers made on this principle of comparing lights by means of a disk of this kind placed between them are now made by Mr. King, of Liverpool,—by Mr. Hulett, who manufactures the photometers known as Church and Mann's,—by Mr. Wright, of Westminster, and others.

The composition at first used for making the paper trans-

Fig. 71.



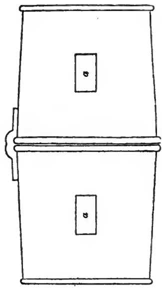


Fig. 72.

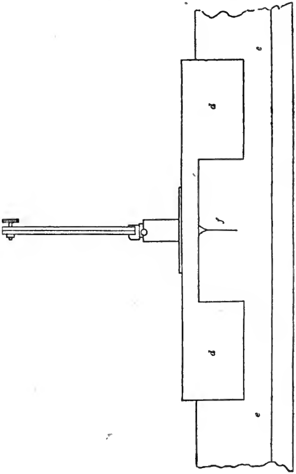


Fig. 74.

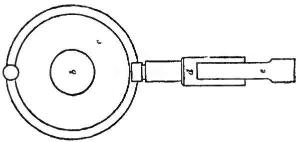


Fig. 73.

parent was melted spermaceti, but Dr. Fyfe recommends spermaceti dissolved in oil of naphtha till it acquires a consistence which is solid at natural temperatures, but is liquefied by the application of a very gentle heat, such as by holding the vessel for a few minutes in the warm hand. He applies the mixture when fluid, leaving in the centre a circle uncovered about the size of half-a-crown. After this the paper is held horizontally over a lamp, and very cautiously heated, so as to make all the inequalities disappear. Dr. Fyfe prefers the fine cream-coloured letter-paper for the purpose of the disk.

Figs. 71 to 74 show the Bunsen photometer as constructed by Mr. Wright. Fig. 71, drawn on a scale of $\frac{1}{20}$th of the full size, is an elevation of the photometer: *a a* is a straight bar of wood carrying at one end a support for a candle, and at the other a support for the gas-burner, which can be screwed on when required. These supports are so placed that the lights are exactly 100 inches apart from centre to centre. Sometimes a meter is fixed at one end in place of the pillar *e*, and the burner is screwed on to a short pipe which passes up from the meter; in other cases a flexible tube *b* is used for conveying the gas to the burner after passing through a meter which registers the exact consumption of the gas: *c* is the moveable carrier supporting the disk, which can thus be placed in any position on the bar: *d* is the centre of the bar from which the divisions commence, the first division in the centre being marked 1 for one candle. The bar is divided into spaces towards the end where the candle is placed, which spaces indicate candles and tenths of a candle, as far as nine candles. From 9 to 20 the spaces indicate half-candles, and from 20 to 36 they indicate only whole candles.

Fig. 72, on a scale of $\frac{1}{4}$ the full size, is an elevation of a blackened shade which is placed over the disk in order to exclude the diffused light of day, and render the determinations on the disk more delicate. It consists of two short wide tubes made slightly conical, and united at top by a hinge which allows them to be separated at the base. The shade is

open entirely through, in the direction of its axis, and when placed over the disk, the surface of the latter is seen, by an observer standing opposite, through the small spaces *a a* in the side of the shade.

Figs. 73 and 74, on a scale of $\frac{1}{4}$ the full size, are an elevation and side view of the disk and carrier. The disk is merely a circle about 4 inches diameter, inserted between two flat metal rings which are kept closed by a small screw. The opaque space in the centre *b* is an inch and a half in diameter, and *c* is the transparent part surrounding it. In these figures *d* is the carrier, *e* is the divided bar, and *f* the pointer marking the division over which the disk stands.

The mode of dividing the bar is very simple when once a Table is calculated for the purpose. For instance, suppose it be required to find x the point of division which shall indicate n candles. Here we have $(100 - x)^2 = n\,x^2$, which being reduced to its simplest form gives the value of

$$x = 100\,\frac{(\sqrt{n} - 1)}{n - 1}.$$

Hence arises a very simple rule for finding the distance from the centre of the candle at which a division must be marked, in order to indicate any required number of candles.

Take out the square root of the required number of candles, and diminish it by 1. Shift the decimal point two places to the right, and divide by the number of candles, less 1. For example, let it be required at what distance the division must be placed to indicate 7 candles. The square root of 7 diminished by unity is 1·6458. This, with the decimal point shifted two places and divided by $7 - 1$, is equal $\frac{164\cdot58}{6} = 27\cdot43$, the distance required.

The following short Table contains a few of the distances for whole numbers of candles, and it is equally simple to calculate those for fractional parts of a candle.

No. of candles.	Distance of division from centre of candle. Inches.
2	41·42
3	36·61
4	33·34
5	30·90
6	28·99
7	27·43
8	26·12
9	25·00
16	20·00
25	16·67

The photometer made by Mr. Hulett for Messrs. Church and Mann has the disk placed at a fixed distance of 10 inches from the candle. This gives the advantage of great simplicity in the division, because the number of candles is always equal to the square of the distance from the disk to the gas-burner divided by 100, or is equal to this square with two figures cut off, as explained when speaking of the Rumford photometer at page 296. As the distance from the disk to the candle is invariably 10 inches in this photometer, the first division, or that for 1 candle, must of course be 10 inches from the centre of the gas-burner, and generally the distance for *n* candles will be equal in inches to $\sqrt{100\,n}$. For instance, the distance of the division for 5·7 candles will be equal to $\sqrt{570} = 23{\cdot}87$ inches. This photometer has certainly one advantage, in the length of its beam being shorter than in the other form where the divisions commence at the centre of its beam, whereas in Church and Mann's the divisions commence at 10 inches from the gas-burner, or from one end of the beam. It follows that a beam of 5 feet, divided according to Church and Mann's system, will contain as many divisions and afford as great a range for comparison as one of 8 feet 4 inches, or 100 inches on the other principle. The advocates for the long beam, however, object to the moving of the candle which is necessary in Church and Mann's photometer, and there are several

other minor arguments for and against the two forms, but these are probably not entitled to any great weight.

EXPERIMENTS ON COAL.

In considering the quantity of the gas produced from a ton of coal, the real value is a function of the volume and of the specific gravity, so that the most convenient mode of expressing the quantity is to give the weight of gas produced, this weight being a compound of the quantity and the specific gravity. In order to reduce a volume of gas of any given specific gravity to pounds avoirdupois, we have only to multiply the volume by the specific gravity in order to find the cubic feet of air equivalent in weight to the volume of gas. Then as a cubic foot of air weighs 536 grains troy, of which there are 7000 in a pound avoirdupois, it follows that the cubic foot of air multiplied by 536 and divided by 7000, or, which is the same thing, multiplied by ·0766, will give the weight of gas in pounds.

Thus let v be the volume of gas in cubic feet, g its specific gravity, and w the weight in pounds avoirdupois. Then

$$\cdot 0766\, v\, g = w.$$

According to this formula the third column of figures has been calculated in the following Table, which shows the weight of gas in lbs. avoirdupois produced by distilling one ton of coal from the principal coal-fields of this country.

Experiments on the Quantities of Gas derived from Coal.

Description of coal.	Cubic feet of gas per ton of coal.	Specific gravity of the gas.	Weight of gas in lbs. avoirdupois per ton of coal.	Authority.
NEWCASTLE COALS.				
English Caking Coal	8,000	·420	257	Dr. Fyfe.
Newcastle Coal	11,648	·475	423	Mr. Joseph Hedley.
Pelaw, Newcastle	11,424	·444	389	Ditto.
Pelton, ditto	11,424	·437	382	Ditto.
Blenkinsopp, Carlisle	11,200	·521	447	Ditto.
Newcastle	8,500	·412	268	London, 1837.
Wall's End, Newcastle	12,000	·490	450	Quantity made in the revolving web retort; authority, Mr. Clegg.
Pelton	11,000	·430	363	Author of the 'Chemistry of Gas-Lighting,' in the 'Journal of Gas-Lighting.'
Leverson	10,800	·425	353	
Washington	10,000	·430	330	
Pelaw	11,000	·420	355	
New Pelton	10,500	·415	335	
Dean's Primrose	10,500	·430	347	
Garesfield	10,500	·398	321	
Gosforth	10,000	·402	308	
West Hartley	10,500	·420	339	
Hasting's Hartley	10,300	·421	333	
Blenkinsopp	9,700	·450	335	
Berwick & Craister's Wall's End	12,507	·470	449	Mr. Clegg.
Pelaw Main	12,400	·420	399	Ditto.
Russell's Wall's End	12,000	·418	384	Ditto.
Ellison's Main	11,200	·416	357	Ditto.
Felling Main	11,200	·410	351	Ditto.
Pearith's Wall's End	11,147	·410	350	Ditto.
Dean's Primrose	11,120	·410	349	Ditto.
Benton Main	10,987	·400	337	Ditto.
Eden Main	10,400	·400	318	Ditto.
Heaton Main	10,400	·410	326	Ditto.
	9,000			Average production by Phœnix Gas Company for year 1848.
PARROT OR CANNEL COALS.				
Yorkshire Parrot	11,500			Dr. Fyfe.

On the Quantities of Gas derived from Coal—continued.

Description of coal.	Cubic feet of gas per ton of coal.	Specific gravity of the gas.	Weight of gas in lbs. avoirdupois per ton of coal.	Authority.
PARROT OR CANNEL COALS—*continued.*				
Wigan Cannel	9,500	·460 to ·520	357	Dr. Fyfe.
Scottish Parrot	9,500	·640	466	Ditto.
Ramsay's Newcastle Cannel	9,7 46	·554 to ·580	423	Ditto.
Loch Gelly Parrot	9,123	·567	396	Ditto.
Lesmahago Cannel, 1st experiment	11,681	·540	483	Mr. Wright.
Ditto do. 2nd experiment	9,878	·650	492	Ditto.
Ramsay's Newcastle Cannel	9,016	·604	417	Ditto.
Ditto ditto	9,333	·598	427	John Kay, Manager of Dundee Gas-Works.
Ditto ditto	9,667	·731	541	Dr. Leeson, Dr. Miller, and Mr. G. H. Palmer.
Lesmahago Cannel	11,312	·737	638	Mr. Joseph Hedley.
Welsh Cannel	11,424	·737	645	Ditto.
Wigan Cannel	11,200	·606	520	Ditto.
Ditto ditto	9,500	·580	422	Liverpool New Gas and Coke Company.
Wemyss Cannel	10,976	·670	563	Mr. Wright.
Ditto ditto	10,192	·691	538	Ditto.
Wigan Cannel	9,408	·478	344	Ditto.
Knightswood Cannel	9,720	·590	439	Ditto.
Boghead Cannel	15,000	·752	866	Mr. J. Evans, at Westminster Station of Chartered Gas Company.*
Lesmahago, No. 1	13,500	·642	666	Ditto.
Ditto No. 2	13,200	·618	627	Ditto.
Capeldrae Cannel	14,400	·577	638	Ditto.
Arniston ditto	12,600	·626	606	Ditto.

* Each of the results given by Mr. Evans is the mean of three experiments.

On the Quantities of Gas derived from Coal—continued.

Description of coal.	Cubic feet of gas per ton of coal.	Specific gravity of the gas.	Weight of gas in lbs. avoirdupois per ton of coal.	Authority.
PARROT OR CANNEL COALS—*continued.*				
Ramsay Cannel . . .	10,300	·548	433	Mr. J. Evans.
Wemyss ditto . .	14,300	·580	637	Ditto.
Kirkness ditto . .	12,800	·562	552	Ditto.
Knightswood ditto .	13,200	·550	558	Ditto.
Wigan (Ince Hall) ditto	11,400	·528	461	Ditto.
Pelton Cannel . . .	11,500	·520	459	Mr. Jos. Hedley.
Leverson ditto . . .	11,600	·523	466	Ditto.
Washington ditto . .	10,500	·500	403	Ditto.
Wigan Cannel . . .	14,453	·640	708	Mr. Clegg.
Ditto ditto. . . .	14,267	·610	664	Ditto.
Scotch ditto. . . .	14,000	·580	622	Ditto.
Ditto ditto. . . .	13,813	·500	529	Ditto.
DERBYSHIRE, WELSH, STAFFORDSHIRE, AND OTHER KINDS OF COAL.				
Derbyshire Deep Main	9,400	·424	308	Mr. Wright.
Brymbo 2-yard Coal .	8,880	·463	315	Ditto.
Powell Coal, 2 cwt. charges every 5 hours	10,165	·459	357	Ditto.
Powell Coal, 1½ cwt. charges every 5 hours	8,250	·470	296	Ditto.
Bickerstaff, Liverpool.	11,424	·475	415	Mr. Hedley.
Neath, South Wales .	11,200	·468	401	Ditto.
Birmingham Gas Company: Lump Coal from West Bromwich . . .	6,500	·453	226	Birmingham Gas Company. Parliamentary return.
West Bromwich . .	6,500	·455	227	Birmingham and Staffordshire. Do.
Macclesfield	6,720			
Stockport	7,800	·539	322	Parliamentary return.
Oldham Watergate and Wigan Cannel mixed	9,500	·534	388	Manchester. Do.
Ormskirk or Wigan Slack	8,200	·462	290	Liverpool, Old Company. Do.

On the Quantities of Gas derived from Coal—continued.

Description of coal.	Cubic feet of gas per ton of coal.	Specific gravity of the gas.	Weight of gas in lbs. avoirdupois per ton of coal.	Authority.
DERBYSHIRE, WELSH, STAFFORDSHIRE, AND OTHER KINDS OF COAL—*continued.*				
Low Moor mixed with two kinds of Slack	8,000	·420	257	Bradford. Do.
Leeds Coal	6,500	·530	263	Leeds Company. Parliamentary return.
Cannel and common Coal mixed . .	8,000	·466	285	Sheffield Company. Parliamentary return.
Derbyshire Soft Coal .	7,500	·528	303	Leicester. Do.
Ditto ditto	7,000	·448	240	Derby. Do.
Ditto ditto	7,000	·424	227	Nottingham. Do.
Staffordshire.				
South's	10,933	·398	333	Mr. Clegg.
Second variety . . .	10,667	·395	322	Ditto.
Third variety . . .	10,667	·390	318	Ditto.
Fourth variety . . .	9,600	·320	235	Ditto.
Forest of Dean . . .	10,133	·350	271	Ditto.
Second variety . . .	10,133	·360	279	Ditto.
Welsh Coal.				
First variety	10,000	·385	295	Ditto.
Second variety . . .	10,133	·380	295	Ditto.

CHAPTER XIX.

ON WATER GAS, OR THE HYDROCARBON PROCESS OF GAS-MAKING.

If the steam or vapour of water be passed through a red-hot iron tube, the steam is decomposed, and hydrogen gas given off in considerable quantities: 10 lbs. or 1 gallon of water will yield 210 cubic feet of hydrogen gas, which, although possessed of considerable heating power, is quite worthless for illuminating purposes. Hydrogen gas, however, has been successfully applied for heating stoves, and when the jets of lighted gas are made to burn in a stove filled up with loose fragments of platinum-foil a very cheerful-looking fire is produced, well known to the public under the name of Bachhoffner's polytechnic fire, from its frequent exhibition at the Polytechnic Institution of London by Professor Bachhoffner.

We are not aware that any systematic manufacture of hydrogen gas has been attempted on the large scale for the purpose of heating, but it will probably not be long before some such proposal will be brought forward. In the meantime several patents have been taken out during the last few years for producing hydrogen gas from water, and bringing it into combination with rich gases derived from oil, resin, tar, naphtha, cannel coal, and other materials which yield highly illuminating gases. Among those who have taken out patents of this kind within the last few years are Donovan, Lowe, Manby, Val Marino, Radley, White, Croll, Webster, Barlow, and Gore.

Although the processes indicated by all these patents differed very slightly from each other, if indeed they are not in some cases perfectly identical, the only one which has been carried out in a really practical manner is that of Mr. Stephen White. Under the patent of this gentleman the towns of

Ruthin, Southport, Warminster, Dunkeld, together with many mills and factories in Lancashire, have been lighted with gas manufactured from water and combined with the gas from resin or cannel coal.

The statements which have been put forth from time to time as to the working of Mr. White's process are exceedingly discordant. Writers on the subject who appear to be imbued with prejudices in favour of the old establishments for making gas from coal and nothing else, declare that the value of the materials used by Mr. White for producing 1000 feet of mixed water and resin gas, equal in quality to coal gas, amount to 2*s.* 10*d.*, while the cost of Newcastle coal to produce the same quality and quantity of gas is only $10\frac{1}{2}d.$ On the other hand Mr. White, the patentee, boldly declares that the cost of materials for manufacturing 1000 feet of his gas is only $3\frac{1}{2}d.$, a disparity so great as to show very clearly a great error on one side or the other, and perhaps on both sides.

However this may be, it is quite certain that the patentee has been supplying gas to several mills in the neighbourhood of Manchester, manufacturing it himself on the premises, and paying all expenses, at the rate of 1*s.* 8*d.* per 1000 feet. In order to do this he has had to remove all the old retorts and fix new ones, but is allowed the use of the gas-holders already on the premises.

The following particulars of the mode in which the hydrocarbon gas is manufactured at Messrs. Clarke and Co.'s mills, in Pollard Street, Manchester, appear to be given without any undue bias, and will furnish a good example of the mode of manufacturing this kind of gas.

The proprietors it seems had erected on their own premises the necessary apparatus for making the ordinary coal gas, consisting of nine horizontal and cylindrical retorts about 6 feet in length, and about 14 inches inside diameter, and from these retorts the usual supply of gas was from 18,000 to 20,000 cubic feet per day. When the patentee undertook to supply his hydrocarbon gas to this mil he removed the old retorts

and erected four new ones, which now yield as much gas as the old ones. The apparatus which Mr. White erected consists of two horizontal retorts of the D shape, measuring each about 6 feet long by an average diameter of 14 inches; and of two vertical retorts called L retorts, each 7 feet long by 9 inches diameter. These are placed in a furnace measuring internally 4 feet 3 inches by 6 feet 6 inches, and so arranged as to economize the fuel necessary for getting up the requisite heats. The gas is produced from resin and water; the resin mixed with residual oil being melted in a small vessel outside the gas-house, is siphoned into the D retort in a liquid state, and is decomposed therein. The water is siphoned from a small tank into the L retort, and entering at the top is decomposed by passing over charcoal and iron scraps at a high temperature. The gas thus produced enters the D retort by a connecting pipe, and in passing through its chambers becomes permanently united with that produced from the resin, forming in this compound state the hydrocarbon gas. The remainder of the apparatus is very similar in general principles to that used for coal gas, with the exception of the purifiers and washers, which are considerably smaller than those required for the coal gas. Besides the resin and water mentioned above, there is a small quantity of charcoal and scrap iron used in the manufacture. The proportions are 1 cwt. of resin, which produces 12 gallons of melted resin; 15 pints of water; $\frac{1}{8}$th of a bushel of charcoal, and $\frac{1}{4}$ ℔. of common scrap iron. These ingredients it is said produce on an average 1500 or 1600 feet of gas and 3 gallons of residual oil, of which 1 gallon is used up with the resin, so that the residual product is, in fact, 2 gallons of oil.

Some very interesting experiments have since that time been made by Dr. Frankland, Professor of Chemistry in Owen's College, Manchester, on the hydrocarbon gas as manufactured at Messrs. Clarke's mills. Dr. Frankland had the whole apparatus placed at his disposal, and minutely examined into the cost of the gas, its composition, and illuminating power.

The following is an abstract of his results:

Cost of production.

First day:

	s.	d.	s.	d.
Resin, 2 cwt. 1 qr. 17½ lbs. at 3*s*. 6*d*. per cwt.			8	5
Coal, 1 cwt. 2 qrs. at 6*s*. per ton			0	5¼
Charcoal, 10 lbs. at 5*d*. per bushel of 20 lbs.			0	2½
Lime			0	1
			9	1¾
Less 10·6 gallons of residual oil at 7*d*.	6	2		
Cask	0	5		
			6	7
Gas produced 3340 feet			2	6¾

Hence the cost of 1000 cubic feet was 9¼*d*. for materials alone.

On the second day the materials, estimated as before, cost 4*s*. 3*d*. for the production of 3800 cubic feet, or at the rate of 1*s*. 1½*d*. per thousand.

Third day, cost of materials 5*s*. 3½*d*.; gas produced 4157 feet, or at the rate of 1*s*. 3¼*d*. per thousand.

Fourth day, cost of materials 5*s*. 8¾*d*. for the production of 3378 cubic feet, or at the rate of 1*s*. 4½*d*. per thousand.

Fifth day, cost of materials 4*s*. 4½*d*. for the production of 3688 feet, or at the rate of 1*s*. 2¼*d*. per thousand.

The working of these five days gives an average cost for materials of nearly 1*s*. 2*d*. per thousand feet.

Dr. Frankland observes, that "in the water-retorts two distinct decompositions take place: namely, first, the decomposition of steam by charcoal, with the production of equal volumes of hydrogen and carbonic oxide gases; and secondly, the decomposition of steam by charcoal, with the formation of two volumes of hydrogen and one volume of carbonic acid. This mixture of hydrogen, carbonic oxide, and carbonic acid, along with a large excess of steam, then passes into the resin retort, where mixing with the decomposing resin vapour it

twice traverses the whole length of the red-hot vessel. There is no doubt that the greater portion of the water gas is produced by the decomposition of this excess of steam in the resin retort, since the weight of charcoal required for the formation of the volume of water gas generated in all the experiments is more than twice as great as that which disappeared from the water retort. This circumstance elucidates the advantages arising from the passage of this gas mixed with steam through the resin retort: the fuliginous matter which would otherwise accumulate and block up this retort and its exit-pipe, as is well known to be the case when resin alone is used, is converted into permanent combustible gas."

Dr. Frankland combats the opinion that the hydrogen of the water enters into combination with the carbon vapours formed in the resin retort, and maintains on the contrary that no portion of the hydrogen enters into any chemical combination whatever, and this he determines in a very clear manner by his analysis of the hydrocarbon gas.

Dr. Frankland's very careful experiments for comparing the illuminating power of the hydrocarbon gas with that of Manchester coal gas gave the following results:

Manchester coal gas.	Hydrocarbon gas unpurified.	Hydrocarbon gas purified.
100	104·2	112·5

Dr. Frankland observes that there is a distinction between unpurified coal gas and unpurified hydrocarbon gas. The former contains sulphuretted hydrogen, ammonia, bisulphuret of carbon, and other noxious ingredients, while the latter does not contain any noxious principle, but simply has its illuminating power diminished by the presence of carbonic acid.

According to Dr. Frankland's experiments, the specific gravity of the hydrocarbon gas was,

Before purification	·65886
After purification	·59133
Specific gravity of the ordinary Manchester coal gas .	·52364

In conclusion, Dr. Frankland remarks on the perfect freedom of hydrocarbon gas from all substances which can prove injurious to furniture, plate, drapery goods, &c., and alludes especially to its freedom from the bisulphuret of carbon, a compound which commonly exists in coal gas, and which has hitherto defied all attempts to remove it.

Dr. Frankland made a further series of experiments at the same works, in order to compare the gas produced from cannel coal alone with that produced by the addition of water gas. These experiments were made in all cases on 112 ℔s. of coal, the distillation being continued until all the volatile matters were expelled from the retort. The water gas was produced as usual, by allowing a thin stream of water to fall upon charcoal, heated to full redness, in a separate retort. This gas, along with the excess of steam, then passed into the lower division of the coal retort, sweeping in its course the gases forming in both the lower and upper divisions rapidly into the hydraulic main, and producing in its passage an additional quantity of water gas by the action of the steam upon the coal tar.

	cubic feet.
From 1 cwt. of the Wigan cannel coal from Ince Hall, Dr. Frankland produced	545
And from the same weight of coal with the addition of water gas	806
From Boghead Cannel.	
Without water gas	662
With water gas	1908
And in another experiment	2582
From Lesmahago Cannel.	
Without water gas	531
With water gas	1459
From Methyl Cannel.	
Without water gas	478
With water gas	1320

	cubic feet.
*From Ramsay's Newcastle Cannel.**	
Without water gas	515
With water gas	751
From Wigan Cannel (Balcarres).	
Without water gas	522
With water gas	775

The comparison of the illuminating power from the simple cannel coal with the illuminating power after the addition of the water gas is one of great importance, as it is on such a comparison that the opponents of the water gas rely. They contend that the water gas dilutes the rich cannel coal gas to a great extent and deteriorates its illuminating power in a high degree. I select from Dr. Frankland's experiments those which were made under strictly similar circumstances, being those only which afford a perfectly fair comparison.

1st. Wigan Cannel (Ince Hall).

	Shadow test. Cubic feet of gas required per hour to produce a light equal to 1 candle.	Number of candles equal to a fish-tail burner consuming 4 feet per hour, pressure ·6 in.	Number of candles equal to a fish-tail burner consuming 5 feet per hour, pressure ·5 in.
Without water gas	·5	18	22·1
With water gas .	·575	15·8	20·0

Boghead Cannel.

The experiments do not appear to have been satisfactorily made in this case, as the water retort delivered its gas into the hydraulic main instead of passing it through the coal retort,

* Dr. Frankland doubts whether the specimen of Ramsay's cannel which he operated upon was genuine. The result seems disproportionate to the known value of this coal as used at the Western Gas-Works, near Kensall Green.

"thus reducing," in the words of Dr. Frankland, "the advantageous operation of the water gas in rapidly sweeping out the illuminating gases from the coal retort, and, in addition, preventing the removal of a considerable amount of carbonic acid, which materially diminished the illuminating power, as indicated by the photometer."

Lesmahago Cannel.

	Shadow test. Cubic feet of gas required per hour to produce a light equal to 1 candle.	Number of candles equal to a fish-tail burner consuming 2 feet per hour.	Number of candles equal to a fish-tail burner consuming 3 feet per hour.	Number of candles equal to a fish-tail burner consuming 4 feet per hour.
Without water gas	·35	12·1	23·2	28·7
With water gas .	·5	9·3	13·2	19·1

Methyl Cannel.

	Number of candles equal to a fish-tail burner consuming 2 feet per hour.	Number of candles equal to a fish-tail burner consuming 3 feet per hour.	Number of candles equal to a fish-tail burner consuming 4 feet per hour.	Number of candles equal to a fish-tail burner consuming 5 feet per hour.
Without water gas	10·1	17·4	21·5	27·8
With water gas .	7·2	10·7	15·3	21·0

Ramsay's Newcastle Cannel.

	Shadow test. Cubic feet of gas required to produce a light equal to 1 candle.	Number of candles equal to a fish-tail burner consuming 2 feet per hour.	Number of candles equal to a fish-tail burner consuming 3 feet per hour.	Number of candles equal to a fish-tail burner consuming 4 feet per hour.	Number of candles equal to a fish-tail burner consuming 5 feet per hour.
Without water gas	·575	8·4	11·9	20·0	24·5
With water gas .	·725	5·8	10·3	14·1	18·8

Wigan Cannel (Balcarres).

	Shadow test. Cubic feet of gas required to produce a light equal to 1 candle.	Number of candles equal to a fish-tail burner consuming 2 feet per hour.	Number of candles equal to a fish-tail burner consuming 3 feet per hour.	Number of candles equal to a fish-tail burner consuming 4 feet per hour.	Number of candles equal to a fish-tail burner consuming 5 feet per hour.
Without water gas	·675	6·0	10·9	14·7	19·9
With water gas .	·7	5·6	9·5	14·1	19·1

PER-CENTAGE COMPOSITION OF THE GASES.

Wigan Cannel (Ince Hall).

	Without water gas.	With water gas.
Hydrocarbons and olefiant gas .	10·81	10·55
Light carburetted hydrogen .	41·99	27·20
Hydrogen	35·94	47·39
Carbonic oxide	10·07	14·86
Carbonic acid	1·19	0

Lesmahago Cannel.

	Without water gas.	With water gas.
Hydrocarbons and olefiant gas .	16·31	10·89
Light carburetted hydrogen .	42·01	18·94
Hydrogen	26·84	55·09
Carbonic oxide	14·18	15·02
Carbonic acid	·66	0·06

Methyl Cannel.

	Without water gas.	With water gas.
Hydrocarbons and olefiant gas .	14·48	11·06
Light carburetted hydrogen .	38·75	22·89
Hydrogen	33·32	45·58
Carbonic oxide	13·40	20·44
Carbonic acid	·05	·03

Ramsay's Newcastle Cannel.

	Without water gas.	With water gas.
Hydrocarbons and olefiant gas .	9·68	9·04
Light carburetted hydrogen .	41·38	26·84
Hydrogen	33·30	44·26
Carbonic oxide	15·64	19·39
Carbonic acid	0·00	·47

No analysis was made of the Balcarres cannel gas.

It appears from these experiments that the illuminating power is invariably diminished after the addition of the water gas. At the same time the compound gas is superior in illuminating power to ordinary coal gas.

Dr. Frankland remarks on the disappearance of carbonic acid from the water gas in its progress through the coal retort as a circumstance highly favourable to the hydrocarbon process. He observes, that the carbonic acid of the water gas is destroyed by some action taking place during its passage through the coal retort, thus obviating all trouble and expense of removing the carbonic acid by any process of purification.

It will be observed from the analysis that the carbonic oxide is always greater after the addition of the water gas, so that it is probable the carbonic acid is destroyed by combining with more carbon derived from the coke in the coal retort, which converts it into carbonic oxide.

In applying the hydrocarbon process to resin, this effect does not take place, as the resin does not furnish the necessary carbon, so that the carbonic acid is not removed.

Dr. Frankland is of opinion that a great part of the addition made by the water gas is not generated in the charcoal retort, but is due to the action of the steam on the carbonaceous matter in the coal retort; attributing it in all probability to the action of steam on the hydrocarbons of the tar.

As Dr. Frankland has not given the quantities of water used, we have no means of knowing whether the whole of the gas capable of being produced by the decomposition of the water enters the hydraulic main, and becomes a part of the mixed gas.

Some experiments made by Messrs. Brande and Cooper at the Royal Mint about the same time, show that when steam is passed into a retort charged with red-hot coke at the rate of 15 gallons of water to 1 ton of coal, a great part of the steam escapes decomposition.

Dr. Frankland's experiments on the illuminating power show that although the diluted gas, as it may be termed, has a lower power than that from cannel coal alone, yet the diminution is by no means in proportion to the increased volume of the gas. Thus taking the first experiments on the Ince Hall cannel, where the volumes of gas, with and without the addition of the water gas, were 806 and 545, the illuminating power with a 4-feet burner was as 18 to 15·8; whereas if the power diminished as the increase of volume, it would be as 18 to 12·1. Again, with a 5-feet burner where the illuminating power is as 22·1 to 20, it would be as 22·1 to 14·9 if diminished inversely as the volume.

So with the Lesmahago cannel, where we have illuminating

powers in the ratios of 23·2 to 13·2 and of 28·7 to 19·1, we should have inversely as the volume, instead of 13·2 and 19·1, an illuminating power of only 8·4 and 10·4. The same kind of proportion holds true with all the other experiments.

Messrs. Cooper and Brande's experiments, however, gave a widely different result, but as most of their experiments were tried on ordinary coal and not on cannel, it is difficult to make a fair comparison.

They have recorded one experiment, however, on Ramsay's Newcastle coal, which may be compared with Dr. Frankland's.

They found, that when the steam of 15 gallons of water per ton of coal was passed into the retort during the distillation, that they obtained 12,586 cubic feet of gas from a ton of coal, while Dr. Frankland's quantity of gas by the hydrocarbon process was at the rate of 15,020 cubic feet.

But the greatest disparity appears when the illuminating power is tried, for Messrs. Cooper and Brande found that their gas from a burner consuming 5 feet per hour gave a light only equal to seven sperm candles consuming 132 grains per hour. Now we have seen that Dr. Frankland's hydrocarbon gas from the same coal gave a light with a 5-feet burner equal to 18·8 candles of 120 grains = 17·1 candles of 132 grains. There must therefore have been some wide difference between the process adopted by Messrs. Brande and Cooper and that of Dr. Frankland.

The hydrocarbon process has several powerful advocates. In addition to Dr. Frankland, the subject has been warmly taken up by Mr. Clegg, who assigns the almost fabulous quantity of 75,000 cubic feet of gas as the produce of one ton of Boghead cannel when treated with the hydrocarbon process. Mr. Clegg estimates the expense of the manufacture at $9\frac{1}{4}d.$ to $11\frac{1}{2}d.$ per 1000 feet of 12-candle gas, and from $11d.$ to $1s.\ 3\frac{1}{2}d.$ per 1000 feet of 20-candle gas. On the other hand, Dr. Fyfe of Aberdeen, who has written and experimented with great ability on the distillation of coal, almost entirely condemns the process, asserting from his own experiments on the hydro-

carbon process with Boghead cannel coal, that in no instance is there any gain in the amount of light from Boghead coal gas by the agency of water in the method recommended by the advocates of the hydrocarbon gas.

In Mr. Clegg's experiments on the hydrocarbon gas he compares the quantities made by the old and the new process by reducing the produce to a standard value of 20-candle gas, that is, gas which when consumed at the rate of 5 cubic feet per hour gives a light equal to that of 20 sperm candles, each burning 120 grains per hour. He also uses a standard for comparison, which he terms that of ordinary London gas, namely, gas which in a 5-feet burner gives a light equal to 12 such candles. The former he terms 20-candle gas, and the latter 12-candle gas.

Mr. Clegg gives the detailed result of his experiments on three kinds of cannel coal, namely, the Wigan, the Lesmahago, and the Boghead.

From the Wigan cannel he states that about 10,000 cubic feet of 20-candle gas can be made from a ton of coal, while by the hydrocarbon process about 16,000 feet of 20-candle gas or 26,000 feet of 12-candle gas may be made from a ton.

He speaks still more favourably of the produce from Lesmahago cannel, which according to him will yield by the common process about 10,500 feet of 40-candle gas.

The same coal by the hydrocarbon process yields per ton 36,000 feet of 20-candle gas, and 58,000 feet of 12-candle gas.

The Boghead cannel, according to Mr. Clegg, yields by the old process about 13,500 feet of gas,* and by the hydrocarbon process about 52,000 feet of 20-candle gas and 75,000 feet of 12-candle gas.

The results of Mr. Clegg's experiments on these three kinds

* Mr. Clegg does not state the illuminating value of this gas, but in the Table below it has been assumed as 40-candle gas,—a supposition which corresponds with Mr. Clegg's other results.

of coal may be further exhibited by stating the whole quantity of light given by a ton of the coal. Thus

Description of Coal.	Number of sperm candles, each burning 120 grains per hour, required to give a light equal to that produced by the gas from one ton of coal. By the common process, or without water gas.	By the hydrocarbon process, or with water gas.
Wigan cannel . . .	40,000	64,000
Lesmahago cannel .	84,000	144,000
Boghead cannel . .	108,000	208,000

In the item of labour Mr. Clegg claims a considerable advantage for the hydrocarbon process. He takes the case of three retorts worked by each method. Under the old system each retort must be charged and drawn either three or four times in the twenty-four hours. By the hydrocarbon process, however, there will be only two retorts to charge and two to draw, as the third retort, which makes gas for the other two, requires only to be replenished with about a shovelful of coke in six hours, and the water, being self-acting, requires no attention.

From these considerations Mr. Clegg calculates the saving in labour at fully 75 per cent.

In the items of fuel, and wear and tear of retorts, Mr. Clegg calculates that the expenses will be about the same under either process of gas-making.

On the subject of purification Mr. Clegg observes, that the only impurity due to the water gas is carbonic acid gas, which is generated in no larger proportion by the hydrocarbon process than when cannel coal is used alone. The opposite of this is the case when the hydrocarbon process is used with resin. When applied to cannel coal, however, Mr. Clegg estimates the cost of purification to be in favour of White's process in nearly the same ratio as the increase of volume.

In comparing the cost of manufacturing gas by the hydrocarbon process with that made under the old system, Mr. Clegg separately estimates the cost of making gas from cannel coal alone, and also that of producing the water gas in connection with coal gas.

The following are Mr. Clegg's estimates for making 1000 feet of coal gas with an illuminating power = 20 candles for 5 feet of gas.

Wigan Cannel, costing 18s. per ton, and producing coke worth 4s. per ton.

	d.
Cannel, 224 lbs., at 18*s.* per ton	21·60
Labour	3·50
Lime	0·50
Repair of retorts, works, and mains	5·00
	30·60
Creditor by coke, &c.	4·
	26·60

Or 2*s.* 2½*d.* per thousand feet.

Lesmahago Cannel, costing 24s. per ton.

Cannel, 213 lbs., at 24*s.* per ton	27·40
Labour	3·50
Lime	0·50
Wear and tear of retorts, mains, &c.	5·00
	36·40

Or 3*s.* 0⅓*d.* per thousand feet.

Boghead Cannel, costing 28s. per ton.

Coal, 166 lbs., at 28*s.* per ton	24·75
Labour	2·40
Lime	0·25
Fuel	4·50
Repairs of retorts, mains, &c.	3·50
	35·40

Or 2*s.* 11⅓*d.* per thousand feet.

His separate estimate for the production of 6000 feet of water gas when made in connection with cannel coal gas, as in the hydrocarbon process, is the following:

	s.	d.
Fuel	0	9
Labour	0	3¾
Repair of retorts, mains, &c.	1	2¾
Coke to decompose water	0	2½
	2	6

Or 5*d.* per thousand feet.

In estimating the cost of the mixed gas made in the hydrocarbon process, Mr. Clegg takes the quantity due to the coal at the ordinary cost of cannel coal gas, and estimates the extra quantity due to the water gas at 5*d.* per 1000 feet, according to the preceding detail.

The following Table presents a condensed view of Mr. Clegg's results as to the comparative cost of gas-making.

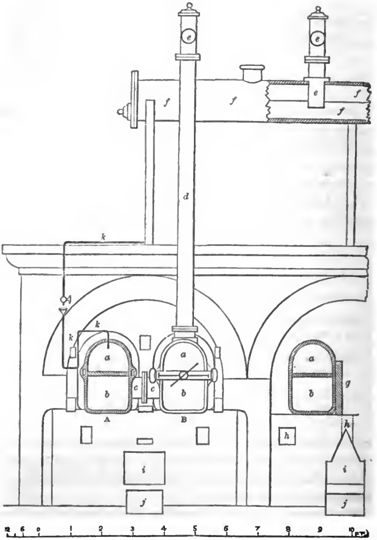
Description of Coal.	Cost of 1000 ft. of 20-candle gas by the old process.	Cost of 1000 ft. of 20-candle gas by the hydro-carbon process.	Cost of 1000 ft. of 12-candle gas by the hydro-carbon process.
	s. *d.*	*s.* *d.*	*s.* *d.*
Wigan cannel, at 14*s.* per ton	1 9¾	1 3½	0 11¼
Lesmahago cannel, at 18*s.* per ton	2 5½	0 11¾	0 9¼
Boghead cannel, at 20*s.* per ton	2 4½	0 11	0 9¼

Mr. Clegg claims several other advantages for the hydrocarbon process, such as the saving of working capital required, and the diminished quantity of coke produced in proportion to the quantity of gas made.

He observes, that the hydrocarbon gas is less liable to condensation and deposit of light-giving material from low temperatures than the ordinary coal gas, and that for domestic use it is decidedly superior, as it does not evolve so much heat or generate so much carbonic acid during combustion as the coal gas.

It appears that water gas is made under Mr. White's pro-

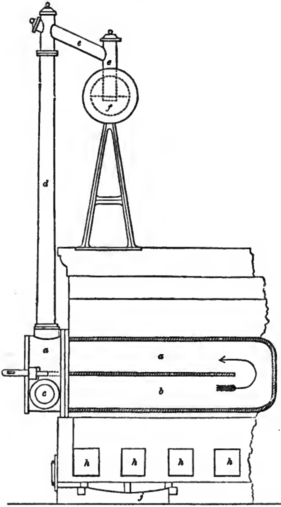
Fig. 75.



cess in several places for heating and singeing purposes, in which case Mr. Clegg states its cost is about the same as that of ordinary gas made from cannel coal alone.

The hydrocarbon process does not appear to have been suc-

Fig. 76.



cessful in combination with resin, as most of the works in which resin was at first used are now adopting cannel coal.

Figs. 75 and 76 show the mode of setting retorts adopted in several small works where White's hydrocarbon process is used. Fig. 75 shows two retorts set in one oven, and part of another oven also containing two retorts. Fig. 76 is a longitudinal section through the centre of one of the retorts.

The ovens for these retorts are 5 feet wide, with semicircular arches, and the length of the retorts exclusive of mouth-piece is 6½ feet. The retorts only differ from an ordinary oval form by having a horizontal partition or diaphragm cast in the centre, dividing the retort into an upper and a lower chamber. This diaphragm extends to within 12 inches from the back end of the retort, and serves to strengthen it.

In the following description the letters of reference refer to the same parts in both figures: *a a a* are the upper chambers of the retorts; *b b b*, &c. are the lower chambers; *c c* is the connecting pipe cast on the mouth-piece and forming an opening between the lower chambers of the two retorts in each oven; *d d* is the ascension pipe, 6 inches inside diameter at bottom and 4 inches at top; *e e*, &c. are the bridge and dip-pipes, the latter of which is shown in both figures dipping into the fluid of the hydraulic main; *f f* is the hydraulic main, 16 inches diameter; *g* shows one of the gnard tiles used to defend the sides of the retorts; *h h h*, &c. are the flues; *i i* is the furnace; *j* is the ash-pan, and *k* is the siphon water-pipe for supplying water to the retorts.

The retorts here shown are 25 by 16 inches, have an internal cubical area of about 16 feet, and the bed of two is capable of producing about 10,000 feet per day of hydrocarbon gas.

The water gas is generated in the retort A in the following manner: the upper and lower chambers are well filled with coke or charcoal, and a very fine stream or rapid drops of water allowed to enter the top of the retort through the water-pipe and siphon *k*. The water falls into a small portable steam-generating tube, which is placed inside to receive it, and here it is instantly converted into steam. The steam in passing backwards along the upper chamber, and forwards along the lower chamber through the red-hot coke or charcoal, becomes thoroughly decomposed into hydrogen and carbonic oxide gases, with a proportion of carbonic acid gas which is removed by passing the gas through a wet-lime purifier.

The water gas generated in the retort A, as described above,

enters the lower chamber of the retort B through the connecting pipe *c c*; the upper and lower chambers of B are charged with cannel coal, through which the water gas passes during the distillation of the coal.

In this passage, the advocates of the hydrocarbon process contend that the water gas exercises a valuable influence by conserving the illuminating powers of the coal gas, increasing its volume at the same time, by accelerating its transit through the retort, and preventing destructive contact with its red-hot sides, and by arresting the formation of tar, much of which is converted into illuminating gas.

In the mode of working which is illustrated by our woodcuts, one water retort is employed for each coal retort, but the patentee states that when very rich cannels or other materials are used, either two, three, or four water retorts may be made to discharge their water gas into the cannel retort.

It may also be observed that in adopting the hydrocarbon process the form of the retorts may be varied to suit existing ovens, also according to the quantity of gas required and the materials to be carbonized.

Although the diaphragm or division plate shown in the engravings is horizontal, this is sometimes made in a vertical position, and cylindrical retorts may be used with either a horizontal or vertical diaphragm.

Vertical retorts have occasionally been employed for the hydrocarbon process, and long retorts, open at both ends, may be used if required.

Amongst the other patentees who have turned their attention to the manufacture of water gas, little has been done in the way of practical operations on a large scale. One or two small works have been erected at St. Ives and other places according to Mr. Webster's patent, which differs very slightly from that of Mr. White.

Gillard's water and platinum gas appears nowhere to have been manufactured except on an experimental scale. His pro-

cess is to form hydrogen gas by admitting steam into a retort where it passes over a layer of incandescent charcoal. The gas is afterwards deprived of its carbonic acid by being passed through lime. The remaining gas, which consists of nearly pure hydrogen, is of course useless for illuminating purposes when burnt in the ordinary way. When consumed, however, in the method pointed out by the patentee, the gas is available both for heating and lighting purposes. If used for lighting, the gas is made to pass through a kind of Argand burner surmounted by a platinum wire wick, something like net-work. It consists merely of a cage of very fine platinum wire on a small brass frame, fitted on to an Argand burner in such a manner that the top reaches a little above the dull hydrogen light, which as soon as the platinum cage is applied is converted into a globe of intense white light over the whole surface of the gauze, with an appearance of an inner flame rising rather above.

Although this light is perfectly pure and brilliant, its illuminating power is by no means great. Probably the chief value of Mr. Gillard's invention is its application to heating purposes, for which it appears well adapted.

CHAPTER XX.

ON THE RATING OF GAS-WORKS IN PAROCHIAL ASSESSMENTS.

After many years of strife and contention, during which extravagant statements have undoubtedly been put forth on both sides of the question, a more rational and sober series of conditions appears to have been agreed upon. The principle is at least firmly established that every property, however great, and however extensive may be its ramifications, is to be rated on the rental which a tenant would give for it as a whole from year

to year, deducting therefrom such expenses as will necessarily be incurred by the owner in order to command such a rental.

In the following discussion I wish to guard myself from any imputation of advocacy on either side of the question. All my inclinations lead me to lean to the side of public companies associated together for purposes of enterprise, and who at the same time are frequently entitled to rank as public benefactors. I cannot, however, conceal from myself the fact, that a great deal of misplaced indignation has been displayed of late years by public companies and their organs on the subject of rating. They seem to have been especially irritated at seeing their property assessed on the same principles as other descriptions of property, and have sought to introduce exceptions and modes of dealing with their particular case which do not appear warranted by the law as it now stands.

I shall not discuss the justice of the present law of rating, but simply endeavour to give, as clearly as I am able, my view of the manner in which it should be carried out, and the way in which gas property should be rated in proportion to other property in the same parish. If powerful joint-stock companies possessing a large interest in the soil, such as railway, canal, gas, and water-works companies, would consider for a moment the number of separate individuals which their gigantic concern displaces, and reflect how large an amount a parish would derive from the separate rating of so many individuals, they would see less reason to complain than at present of the injustice of parochial rating. From a parliamentary document which appeared a few years ago, it appears that the London and Birmingham Railway proper, 112 miles in length, was rated to the relief of the poor on a net rateable value of £134,159. Now this rateable value applies to an expenditure of at least four millions sterling in works, buildings, and other stationary property which is clearly rateable, so that the value on which the railway is rated would be about 3·3 per cent. on the fee-simple of the property. But conceive the same amount of four millions sterling invested in buildings of

any description, it will be admitted by most persons who have attended to the subject, that such a rating is far below that which would be applied to buildings; and that, in fact, a rateable value equal to 6 or 7 per cent. of the value is by no means unusual. While on the one hand it is highly unjust for public companies to be rated for a mere local purpose at a higher proportionate rate than other properties, it is also manifestly unfair that they should escape local taxation to a greater extent than any other kind of property.

In proceeding to rate any description of property extending into many different parishes, such as a gas-work, a railway, a canal, or a water-work, it is necessary first to determine the net rateable value of the whole, and then to apportion this net rateable value amongst all the parishes in which the works are situate. I shall first consider the mode of ascertaining the rateable value of the property as a whole, and then proceed to the method of subdividing or apportioning this amongst the parishes.

Now in order to arrive at the rateable value of the whole we are clearly to be guided by the words of the Act 6th and 7th William IV. chap. 96, which enacts that property is to be assessed first at that rent which it might reasonably be expected to let for from year to year, and then that the net rateable value is to be found by deducting from this annual rent such expenses for insurance, repairs, &c. as will enable the property to command such rent. The exact words of the Act, which is commonly called the Parochial Assessment Act, are as follows: "That no rate for the relief of the poor in England and Wales shall be allowed by any justices, or be of any force, which shall not be made upon an estimate of the *net* annual value of the several hereditaments rated thereunto; that is to say, of the *rent* at which the same might reasonably be expected to let, from year to year, free from all usual rates and taxes, tithe commutation rent charge, if any, and deducting therefrom the probable average annual cost of repairs, insurance and other expenses, if any, necessary to maintain them in a state to command such rent."

The first thing therefore in rating a gas-work is to determine the rent at which it may be expected to let from year to year, and here immediately and directly arises the necessity for a reference to the company's balance sheet, in order to find out the profit which the company is making. It has happened in the absence of such a document, when access to the company's books has been refused from some cause or other, that valuers have been required to form an estimate of the annual value from independent calculations of their own, in which the cost of manufacturing the gas is deduced from certain data real or imaginary, and a profit assumed as the amount realized by the company. I shall not stop to inquire into the mode of so estimating the profits of a gas-work, although when the amount of coal carbonized is known, the number of retorts being given, the locality and other circumstances being taken into consideration, a tolerably fair approximation may be made. I am only desirous at present to establish, as a foundation to proceed upon, that the profit realized by the company in any one year is the basis or ground-work from which the rateable value must be derived.

This point should be clearly settled at the outset, because it has been contended more or less ever since 1836, when the Parochial Assessment Act passed, that such a mode of assessment was unfair with respect to railways and similar works. It has been said that in seeking to ascertain the profits of a railway company you are seeking to rate them on *profits*, which is expressly forbidden by a short Act which is passed every session for the purpose of exempting stock in trade from liability to be rated. But on the other hand it is to be observed, that the inquiry into profits is rendered necessary in order to ascertain what the property would let for, and this is precisely that which is directed to be ascertained by the Parochial Assessment Act. The necessity for inquiring into profits is supported by every example that can be brought to bear on the subject.

In the case of rating ordinary houses the gross annual value is a very simple affair, because the house has generally a tenant who does actually pay a rent for it, and even if in the land-

lord's occupation, the value to let is easily inferred from comparison with similar houses; but when we come even to the most simple case of premises deriving a peculiar value from situation, manufacturing power, or any other circumstances, we require to know immediately the amount of profit which annually arises from such circumstances. Thus we may know perfectly well, without any inquiry into profits, what all the houses in any particular street will let for; but suppose one house to be fitted with a billiard-table from which the tenant derives a profit, we shall require to know the amount of this profit before we can estimate the additional value to let which is conferred by the billiard-table.

The same remark applies to peculiar situation and to manufacturing power as where machinery exists on the premises. In all these cases, where the landlord holds or occupies the property himself, we ought to know the profit which he derives before we can possibly estimate the value of the property to let from year to year.

Admitting then that the profit must be inquired into, there are two ways of arriving at this, either by taking it from the company's books of account, or making an independent estimate of what the profit ought to be. In the case of railway companies, the business carried on is so extensive and complicated that as a matter of necessity the parochial officers and persons acting for them are compelled to take the profit from the accounts of the company, usually from the accounts published for their half-yearly meetings. In the case of gas companies, however, some of which are not under the most efficient management, it is not unusual for valuers to make their own estimate of the profits on certain known *data*, which are perhaps admitted on the part of the gas company. I shall not at present enter into the mode of estimating the productive power, and consequently the profit of a gas company, but suppose that this has been ascertained by one or other of the means pointed out, and that the profit is found to consist of a certain sum which remains after deducting the total ex-

penditure of the year from the gross receipts during the same period.

We have now arrived at the profit made by the company whilst the works are in their own occupation, but this is not the sum which a tenant will give for them, because he must not only have a certain sum left for himself as a remuneration for his time and superintendence, but must have interest for the capital employed to carry on the works.

The amount and nature of these arbitrary allowances for the tenant have given rise to great disputes, and the utmost variety of opinion is entertained on the subject. It appears to be an admitted principle on all sides that the tenant is to be allowed a certain amount of capital to carry on the works, that is, to pay for coal, lime, wages, &c. until his returns are received for gas and coke sold; and also that he is to be allowed for capital corresponding in amount with the present value of such machinery as comes under the denomination of stock in trade, and which cannot be rated as forming a part of the premises, or an hereditament attached to the soil.

On the part of the gas company the whole yearly expenditure is first deducted from the gross receipts, including such items as wear and tear of retorts, loss by meters, rates and taxes, directors' and auditors' salaries, bad debts, &c. The balance which remains is then subject to what are termed arbitrary allowances for tenant, in which his capital is made to consist of the following items:

1. Capital required to enable him to carry on the works, usually estimated by valuers for the companies at about half the gross expenses for one year.

2. The present value of the meters, retorts, and other stock in trade.

On the capital so arrived at, it is assumed that the tenant would require 5 per cent. for interest and 12½ per cent. for profit, which amount is therefore deducted from the gross value as an arbitrary allowance to the tenant.

On the other hand, the parties usually employed to value for

the parishes, contending that directors' and auditors' salaries being already allowed for in the expenses, make this a set-off against the remuneration of the tenant. Considering further the perfect security for payment which the Act of Parliament gives to most gas companies, the means which they have of enforcing payment, and the small amount of risk incurred in carrying on their business, they contend that such an allowance of $17\frac{1}{2}$ per cent. for capital is excessive, and ought not to be more than 10 or at most 15 per cent. Then as to the amount of capital, they seem to have generally allowed the retorts to be stock in trade, but not the meters, which they consider fixtures to the mains, and therefore subject to be rated.

An example of estimates formed on these varying principles will be shortly given, from which it will be seen how widely these arbitrary deductions vary according to the views adopted by the valuers.

I now come to the class of deductions comprised under the head of statutable allowances, comprehending all those (such as rates, taxes, insurance, and repairs) which are necessary to enable the premises to command the rent assumed. Here the valuers for gas companies have sought to bring in charges for repairs, or rather for restorations, which are said to be necessary, in addition to those which appear in the annual current accounts. For instance, they claim an annual allowance for the repair of buildings, although the accounts include every farthing which has been expended in such repairs.

They also claim an allowance for insurance of buildings beyond any amount which is actually paid for such a purpose. Besides which they claim an allowance of 2 per cent. on the value of all their trade fixtures and utensils, and of $1\frac{1}{2}$ or 2 per cent. on the value of all the mains, for the reproduction of these when worn out. The valuers for parishes, on the other hand, entirely dispute these allowances, and contend that the current expenses provide for such reproduction by having everything renewed as fast as it is worn out and requires to be replaced.

Some years ago, in the rating of railways, very extravagant

allowances were claimed, on the same principle, to cover the reproduction of the rolling stock and of the permanent way. It was, however, frequently suggested that if any provision were necessary for such a purpose, the railway company should itself set aside a sum annually, by way of sinking fund, to cover such an expense when found necessary. In certain cases where no such fund was set aside by the railway company, the allowance for reproduction was refused on the rate being appealed against. There is still a difference amongst railway engineers, however, as to the necessity for a depreciation fund. The London and Brighton Railway Company, acting probably under the advice of their able Chairman Mr. Lang, who possesses a vast amount of practical experience and valuable statistical knowledge, has been in the habit for some years of setting aside a sum out of its receipts to form a depreciation fund. On the other hand, such a fund has been declared altogether unnecessary by one of the most eminent and accomplished railway engineers of the day, who has devoted himself to every question of railway politics with an energy and industry peculiarly his own. I need scarcely say that I allude to the originator of the broad gauge, who has publicly declared that the current accounts of the Great Western Railway include such expenses as are necessary, from time to time, for keeping in perfect order both the rolling stock and the permanent way, and that no annual reserve in the shape of a depreciation fund is necessary for their maintenance.

I am aware that there are many rating cases which are tried on appeal at Quarter Sessions, where an intimation is given by the Bench that some allowance for depreciation should be made to the company beyond that which appears in their accounts. In addition to this, in the valuing of houses, manufactories, and many other descriptions of property, where no accounts of repairs have been kept, or where it appears clear that a charge for restoration will accrue suddenly at some future time, and cannot be provided for by annual repairs and restoration, it may be necessary to calculate on

sound principles what the allowance should be for such a purpose. It will not be sufficient in such a case to assume any mere arbitrary allowance on the cost, such as $1\frac{1}{2}$, 2, or 5 per cent., all of which sums have been claimed for reproduction, but it must actually be ascertained what sum under the given conditions of the question will be an equitable allowance for the purpose. There are two elements which must be assumed in any case of this kind; first, the value of the object to be restored, and the period or distance of time at which the restoration is to be made. The value must not be the original value of the object when first erected, but its value at the time of making the rate, and when once the sum to be set aside annually is determined, it will be the same year after year, because, although the value of the object will diminish yearly, so also, in the same proportion, will diminish the number of years during which the annual sum is to be set aside. The principle I am now contending for is this, that the annual sum to be set aside is that sum which at compound interest will amount in the assumed number of years to the whole sum required at the end of that number of years to effect the restoration. For instance, suppose a building or any other object whose present value is £1000 should be assumed to last thirty years, when an amount of £1000 must be employed to restore it; then, I say, the annual sum to be put aside is that which at compound interest, at 3 per cent., will amount in thirty years to £1000. Now, it appears from the tables of compound interest that £1 per annum invested at compound interest during thirty years will amount at the end of that time to £47. Hence it follows, if we divide 1000 by 47, we shall have the sum which, being invested annually at compound interest, will at the end of that time produce £1000. Then $\frac{1000}{47} =$ £21. 5*s*. 8*d*., the sum to be invested annually. This would amount to rather more than 2 per cent., which is the proper allowance when the duration is estimated at thirty years.

When a period of twenty years is taken for the duration of an object, an allowance of nearly 4 per cent. must be made.

When the period is 30 years, 2 per cent.

" 40 " 1·3 "

" 50 " ·88 "

The following estimate, made by Mr. Lee, of the net rateable value of the Phœnix Gas Company, forms a good example of the mode usually adopted by the valuers of gas companies for assessing the rateable value. This valuation was made in 1849 on the occasion of an appeal by the Phœnix Gas Company against the rate in the parish of Greenwich.

	£.	s.	d.	£.	s.	d.
Net balance for 12 months, taken from the Company's Books				21,964	12	0
Arbitrary deductions to arrive at the gross estimated rental:						
Floating capital employed by tenant, assumed equal to 6 months' expenses	33,210	0	0			
Present value of meters, the cost being £25,000	15,000	0	0			
Present value of retorts	7,525	0	0			
Total amount of tenant's capital .	£55,735	0	0			
5 per cent. for interest on £55,735 is .	2,786	0	0			
12½ per cent. for tenant's profit on £55,735	6,966	0	0			
Amount of interest and tenant's profits for one year .				9,752	0	0
Gross estimated rental				12,212	12	0
Statutable deductions.						
Rates and taxes previously deducted in arriving at net balance; annual repairs of buildings previously deducted:						
Insurance on buildings, value £65,054, at 5*s*.	162	0	0			

				£.	s.	d.	£.	s.	d.
Brought forward				162	0	0	12,212	12	0
2 per cent. for reproducing the following:	£.	s.	d.						
Trade fixtures, value	39,672	0	0						
Utensils . . .	12,945	0	0						
Mains in the stations	6,271	0	0						
Street mains . .	105,760	0	0						
	£164,648	0	0						
2 per cent. on £164,648				3,292	0	0			
Total deduction for renewal and insurance . .							3,454	0	0
Net rateable value of the whole property, the value being £278,998							£8,758	12	0

It appears that the valuers for the parish during this appeal did not treat the production of the Phœnix Gas-Works as a whole, but confined their estimates to the production of the Greenwich Station alone, whereas the company has also manufacturing stations at Vauxhall and at Bankside. In conse- of this no comparison can be made between the net rateable values arrived at by the two parties, treating the works as a whole. Mr. Penfold, however, in his work on Rating, has published a statement of net rateable value for the whole works, founded on the basis of the Company's own rental, and on arbitrary allowances, according to Mr. Barlow's statement of expenses for manufacturing gas. This statement is taken from an able Report made by Mr. Barlow in 1849 to the Directors of the City of London Gas Company. In his Report, Mr. Barlow analyses with great minuteness the prospects of the Great Central Gas Consumers' Company. He investigates the cost of every item of gas manufacture under two distinct heads, *production* and *distribution*, making the total cost of production amount to 20·64*d*. per 1000 feet of gas made, and the expense of distribution equal to 13·51*d*. per 1000. Mr. Penfold, considering Mr. Barlow as the especial advocate of the then existing companies, and interested in proving the

cost of gas-making to be as high as possible, considers such statements fair evidence as against any gas company on the question under discussion.

Using the data before explained, Mr. Penfold makes the net rateable value of the whole of the Phœnix Company's Gas-Works	£18,312
And substituting Mr. Croll's cost of manufacturing gas, as given in evidence before the Central Gas Committee, he makes the net rateable value of the whole . .	28,455
Mr. Lee's valuation of the rateable value being . .	8,758

We shall present one other case in which the author was himself engaged, and Mr. Lee valued for the gas company. This was the case of the British Gas Company and the Parish of Ratcliff. Mr. Lee's valuation in this case was nearly on the same basis as in the Greenwich case, except that the estimates claimed only $1\frac{1}{2}$ instead of 2 per cent. for the reproduction of the mains. The following is Mr. Lee's valuation:

Cr.	£.	s.	d.	£.	s.	d.
Total rental for gas light . . .	21,188	0	0			
Cash for coke and ammonia . . .	4,544	0	0			
Total receipts for 12 months				25,732	0	0

Dr.		£.	s.	d.
Coals, 12,322¼ tons used (at 14*s.* 10½*d.*) . .		9,153	0	0
Lime used for purifying.		267	0	0
Working process wages.		5,092	0	0
Wear and tear of retorts, &c.		2,020	0	0
Meter repairs and fixing .	£882			
Meter rent rec^d.	400			
Loss		482	0	0
Rates and taxes (last year, 1848) . .		650	0	0
(Rates in 1849 are larger.)				
Carried forward .		17,664	0	0

	£.	s.	d.	£.	s.	d.	£.	s.	d.
Brought forward .	17,664	0	0				25,732	0	0
Office expenses and clerks' salaries	742	0	0						
Directors' salaries . .	500	0	0						
Ordinary law expenses .	70	0	0						
Interest on borrowed capital . £1395									
Bad debts and overcharges	400	0	0						
							19,376	0	0
Net balance for 12 months							6,356	0	0
Deductions to arrive at the gross estimated value 5 per cent. on the capital* necessarily employed by a tenant .	11,500	0	0						
Ditto on the present value of meters (the cost being £5,640) .	3,640	0	0						
Ditto on the present value of retorts (cost £4,680)	2,420	0	0						
Amount of tenant's capital .. .	17,560	0	0						
5 per cent. on the above is				878	0	0			
Amount of tenant's profit, being 12½ per cent. on the above £17,560 capital .				2,195	0	0			
Amount of interest and tenant's profit for 12 months							3,073	0	0
Gross estimated rental of the whole property . .							3,283	0	0
Statutable deductions.									
The rates and taxes are before deducted.									
Annual average repairs of buildings .				390	0	0			
Insurance on buildings				106	0	0			
Carried forward				496	0	0	3,283	0	0

* The capital here assumed is considerably more than six months' expenses, and is nearly equal to six months' gross receipts.

	£. s. d.	£. s. d.
Brought forward	496 0 0	3,283 0 0
For renewal or reproducing trade fixtures and utensils, their value being £16,847 (meters not included), at 2 per cent.	336 0 0	
For ditto ditto, the mains on the stations and the street mains, their value being £24,453, at 1½ per cent.	367 0 0	
Total of repairs, insurance, and renewal . . .		1,199 0 0
Net rateable value of the whole property . .		£2,084 0 0

It being considered that this rateable value was too small, having regard to the magnitude and capacity of the works, the author was called in by the Parish at the suggestion of Mr. Penfold, who was one of the arbitrators, and after going through the works and minutely considering the Company's evidence to see what parts could be adopted as reasonable and fair, the result of his investigation was the following estimate:

Net rateable Value of all the Works and Mains.

	£. s. d.		£. s. d.
Gross revenue, as per statement A			24,172 17 3
Production account:			
Coal, as per evidence .	9,153 0 0		
Labour of distilling 12,322 tons of coal, as per statement B .	2,261 5 0		
Wear and tear of retorts, as per statement C .	1,333 13 0		
Expense of lime for purifying 12,323 bushels, at 4*d*. . . .	205 8 0		
	12,953 6 0		
Less residual products, as per statement D .	4,601 13 4		
		8,351 12 8	
Carried forward		8,351 12 8	24,172 17 3

	£. s. d.	£. s. d.
Brought forward	8,351 12 8	24,172 17 3
Cost of distribution, as per statement E	3,276 7 3	
Statutable allowances, as per statement F	1,219 18 0	
Arbitrary deduction for interest and tenant's profit, £10,000, at 15 per cent., as per statement G	1,500 0 0	
		14,347 17 11
		9,824 19 4
Deduct rates and taxes, as per Company's statement		650 0 0
Net rateable value of the whole property		£9,174 19 4

A.

Estimate of Gross Revenue.

12,322½ tons of coal carbonized per annum, each ton assumed to yield 9200 cubic feet of gas.

			£. s. d.
Then 12,322½ × 9200 =		113,367,000	
Less ¼ for leakage		28,341,750	
Total quantity to be sold		85,025,250	
From this deduct consumption of 1264 public lights, each at 50 feet per night, making 1264 × 50 × 365 =	23,068,000		
Deduct also quantity used in Works, as per evidence	1,000,000	24,068,000	
Private consumption		60,957,250 at 6s.	18,287 2 0
Receipts for public lights, as per Company's evidence			5,885 15 3
			£24,172 17 3

B.

Estimate of Expense for the Labour of manufacturing Gas from 12,323 tons of Coal.

	£.	s.	d.
Salary of superintendent	200	0	0
Foreman, at 36s. per week	93	12	0
Two foremen of stokers, at 30s. per week each	156	0	0
Twenty ordinary stokers, at 24s. each	1248	0	0
Wheeling coal, 12,323 tons, at 3d.	154	1	0
Two purifying men, at 24s. each	124	16	0
Valve man, at 28s.	72	16	0
Storekeeper	80	0	0
Coke clerk	80	0	0
Gatekeeper	52	0	0
	£2261	5	0

C.

Wear and Tear of Retorts.

In this estimate it is assumed that each retort will be worn out, and require to be taken down and re-set, after producing 700,000 cube feet of gas. Hence the number of retorts required per annum will be $\frac{113,367,000}{700,000} = 162$ retorts, which are assumed to be of cast iron, weighing 16 cwt. each.

	£.	s.	d.
Hence 162 retorts, at £5	810	0	0
Taking down 162 old retorts, breaking the connections, and renewing old materials, 162 at 4s.	32	8	0
Bricklayers' wages for re-setting retorts, 162 at 12s. 6d.	101	5	0
Fire-clay and fire-bricks used in re-setting retorts and in repairing furnaces, 162 at 20s.	162	0	0
Making good connections to hydraulic main	26	0	0
Bolts and cement for new connections, wear and tear of ash-pit pans, furnace-doors and bars, ears and cross-bars, barrows, scoops, shovels, brooms, &c., 162 at 10s.	81	0	0
	1,212	13	0
Allowance for contingencies, defective retorts, &c., 10 per cent.	121	0	0
	£1,333	13	0

No deduction is here made for the sale of the old retorts.

D.

Residual Products.

Total coal used . . .	12,322 tons.
Making	12,322 chaldrons of coke.
Used for carbonizing, ⅓rd .	4,107
Remaining for sale . . .	8,215 chaldrons.

	£.	s.	d.
8215 chaldrons, at 10s.	4,107	10	0
100 tons of coal will yield 8 chaldrons of breeze, to be sold for brick-making, at 3s. per chaldron.			
Hence $\frac{12,322 \times 8}{100} = 985$, at 3s.	147	15	0
Each ton of coal will yield 10 gallons of gas tar.			
Hence 123,220 gallons, at 1d.	513	8	4
	4,768	13	4

Deductions:

	£.	s.	d.	£.	s.	d.
Filling 9200 chaldrons of coke and breeze, at 3d.	115	0	0			
Labourers delivering tar and ammoniacal liquor	52	0	0	167	0	0
				£4,601	13	4

E.

Expenses of Distribution.

	£.	s.	d.
Lighting and repairing 1264 public lamps, at 20s. . .	1,264	0	0
Collection and bad debts, at 3 per cent. on rental of £24,000	720	0	0
Law expenses, stationery, and incidental expenses, 113,367 at 1d.	472	7	3
Engineer, secretary, clerks, and inspectors . . .	820	0	0
	£3,276	7	3

Engineer	£200
Secretary . . .	200
Two Clerks	150
Three Inspectors . .	270
	£820

F.

Statutable Allowances.

	£.	s.	d.
Insurance of buildings, and annual repairs of buildings and apparatus	500	0	0
Renewal or reproduction of trade fixtures, valued at £17,644, at 2 per cent.*	352	18	0
Renewal of mains, valued at £24,453, at 1½ per cent.* .	367	0	0
	£1,219	18	0

G.

Estimate of Capital required by Tenant.

	£.	s.	d.	£.	s.	d.
Coal in stock, 2000 tons, at 15s.				1,500	0	0
One year's consumption of coal	9,153	0	0			
One year's wages for manufacturing, as per statement B	2,261	5	0			
One year's wear and tear of retorts, as per statement C	1,333	13	0			
One year's expenses of distribution, as per statement E	3,276	7	3			
One year's maintenance of works, repairs, insurance, &c.	500	0	0			
	16,524	5	3			
Deduct one year's receipts for sale of coke .	4,601	13	4			
	£11,922	11	11			
The tenant would have to provide for half-a-year's payments, or $\frac{11923}{2}$				5,961	10	0
Assumed value of retorts, as per evidence				2,420	0	0
				£9,881	10	0

* These allowances were made because in former cases they had been decided at Quarter Sessions. The amounts being small, it was not thought advisable to complicate the case by contending for the principle of a sinking fund, which, as already explained, is the proper way to estimate costs of reproduction.

DIVISION OF THE NET RATEABLE VALUE BETWEEN THE SEVERAL PARISHES.

We now come to the second branch of inquiry; namely, the mode of apportioning the net rateable value, as determined for the whole gas-works, amongst the several parishes through which the mains extend. Here again we find quite as great a variety of opinion as on the other subject. Even the judgments delivered by the Court of Queen's Bench, the highest court of appeal to which rating cases have been carried, seem to have undergone some change year after year since the passing of the Parochial Assessment Act. It appears to be clearly decided, in the case of the Queen *v.* Cambridge Gas-Light Company, that the rateable value is not to be divided in proportion to the *receipts* for gas in each parish; and Lord Denman, in his judgment in this case, quoted a parish through which the New River passed, and in which no profits accrued to the Company, yet the New River Works in this parish were rated, and properly so, at £300, because the apparatus in the parish contributed to the whole value to let, although no receipts within the parish itself were derived from the apparatus lying within it. So it will often happen in the case of gas-works that mains may pass through a parish without any service-pipes being affixed to them, without supplying any gas in the parish, and consequently not yielding any receipts. But the works are nevertheless to be rated in this parish because they carry gas which passes through them for the supplying of other parishes where the Company receives payment for its gas. Some of the judgments even seem to have inclined to the opinion, especially in the case of railways, that the total rateable value should be divided in proportion to the mileage or length of line passing through each parish. This division, however, would usually be very unjust alike for railways, gas-works, and all similar undertakings. In each case the most remote and thinly inhabited parishes would reap far more

than their share, while metropolitan parishes, and chiefly those nearest to the principal termini or principal sites of manufacture, would be injured in a proportionate degree. Other decisions, however, and those of a more recent date, have supported an opposite principle,—namely, that of dividing the net rateable value of the whole in proportion to the quantity of apparatus in each parish. Lord Denman, in his judgment in the case of the Queen *v.* the Cambridge Gas-Light Company, speaking of the division amongst the parishes, says, "we are aware of no rule which can be laid down as to the amount, except that it must be in proportion to the quantity of apparatus situate in each parish."

In the next case of importance, namely, that of the Queen *v.* the South-Western Railway Company, a somewhat clearer principle was expressed; and in the case of railways it was decided that the division should be in proportion to the earnings in each parish, having first deducted from the net rateable valne of the whole the rateable value of the stations, which are separately rated in the parishes in which they are situated. Now in the case of a railway this mode of division is quite practicable, and no parish wonld be excluded from its just proportion of the whole assessment, even though no receipts are actually taken in it. Suppose a parish situate between two stations A and B, then the whole of the traffic passing from A to B and *vice versâ* will pass through the parish. The parish accordingly will be entitled to its proportion of the receipts taken for traffic between A and B in proportion to its length, so that the case is amply provided for in which a parish has no station, and in which consequently no receipts are taken by the Company.

The case is equally simple when the parish contains a station; the net rateable value here being a proportion according to mileage of the receipts between the station in the parish and that on each side of it, with the addition of a sum for the station itself. It would lead us too far out of our way and be altogether inapplicable in this work to go further into the

mode of dealing with the railway stations and separating their rateable value from that of the railway proper; and we must therefore confine our attention more immediately to the case of gas-works. Here, however, the same general principle prevails for separating the works,—that is, all the rateable apparatus at the head-quarters or manufacturing establishment from the pipes or mains extending through the streets. No satisfactory or even practicable mode of doing this has ever been suggested, except that arising from the cost or value of the *works* as compared with that of the whole property, *works* and *mains together*. We shall suppose the net rateable value of the whole to have been arrived at, and, in order to find the separate part of this chargeable to the works and to the mains, we must have an estimate of the present value of the works and of the mains separately. Then we have this proportion:

As the present value of the works and mains together is to the net rateable value of the whole, so is the present value of the works to the net rateable value of the works. In the same way the net rateable value of the mains is found by substituting the present value of the mains for that of the works in the third and fourth terms of this proportion.

The principal station or manufacturing site of a gas establishment is commonly at least equal in value to that of the mains, so that in this simple mode we get rid of half the rateable value by apportioning it to that parish in which the manufacturing station is situate. If there be more than one station the division is equally simple, each station being debited with its proportionate rateable value according to its present worth, as compared with the worth of the whole property.

We have yet a further sum, however, to divide amongst the mains, and perhaps this division has given rise to more contention than any other question connected with the rating of gas-works. In the case of the Phœnix Company and the Parish of Greenwich, the Court of Quarter Sessions decided that the

division was to be made in proportion to the square yards of ground occupied by the mains in each parish. Now, with great submission to the learned Bench of Magistrates, this decision was simply absurd, because the square yards of ground occupied are neither a measure of the quantity of apparatus, nor a measure of the earnings, nor a measure of the capacity of the mains. This mode of distributing the rateable value has the effect of giving an enormous advantage to the remote parishes, and in a proportionate degree injuring those which are nearest to the fountain-head, and which first distribute the gas before it begins to be taken out of the mains.

Another principle of division which has been adopted is also fallacious, but not to the same extent, namely, that of dividing the rateable value according to the cubic yards of main in each parish. This principle makes a perfectly correct division according to the quantity of apparatus, but not according to earnings, which by the latest decision is clearly intended to be the basis of the subdivision. The error is of the same nature as the one allowed by the Quarter Sessions in the Phœnix case, namely, one of excess for the remote parishes, at the expense of those near the centre of distribution. The principle, in fact, of dividing according to cubical capacity of the mains is only correct on the supposition that a main of a given area will deliver the same quantity of gas at all distances from the gas-holder, which we know is very far from being the fact. Every one knows that a 12-inch main within 100 yards of the gas-holder will pass a great deal more gas than the same main at the distance of a mile. The principle in question would also require this theoretical condition, namely, that the mains at the extremities of the Company's district should be attenuated to such dimensions as just to deliver the gas required for present consumption with the requisite pressure; but this is notoriously not so, for with a view to extensions the mains are purposely not so much contracted as they otherwise might be. The effect of all this is, that this mode of subdivision does not give to the mains their proportionate value as parts of

the apparatus in the arterial parishes, and gives too much value to those at a distance. It divides the rateable value in proportion to quantity of apparatus, not with reference to earnings, nor with reference to capacity for earning or contributing to the whole earnings of the concern.

I am now bound to explain the mode in which I propose to subdivide the rateable value amongst the mains, for which purpose I must have the cubical contents of all the mains, the cubical contents in the particular parish, the quantity of gas supplied in that parish, and the annual receipts for that gas. Then I should calculate the size of main which would be required simply for the delivery of the quantity of gas consumed in the parish, and consider the extra size of the main, entitled to a further allowance for contributing to the earnings of the parishes lying beyond. Thus, I would say,

As the whole receipts are to the rateable value of the whole, so are the receipts in the parish to the rateable value of the mains, in respect of receipts within the parish.

Then, to find the additional rating for the part contributed by the mains towards the receipts in other parishes, I would say—

As the cubical content of all the mains is to the extra cubical contents of main in the parish beyond what would be necessary for the supply of the parish, so is the rateable value of all the mains to the extra rateable value of mains in the parish. The fourth terms in each of these proportions being added together would give, as I conceive, the whole rateable value of the mains in any parish.

I am afraid of extending this subject of rating to too great a length, as it might be wearisome to many of my readers. At the same time, the subject possesses much interest for gas companies, who would in many cases fare better if they did not attempt to shroud this affair in such impenetrable mystery. This air of mystery is often apt to occasion a suspicion of far greater profit than that really derived. In all such cases fair play to the parishes is to be insisted on;

let each have its proper share, and let each have such means of information as will enable its officers to make assessments on a sound basis.

It has not occurred to me now for the first time, considering the many complicated interests which have to be assessed in these days of progressive improvement, that it would be desirable if some public officer were appointed to make an assessment every year of the property in gas-works, canals, railways, &c., rateable to the relief of the poor. Such an assessment would require to be varied every year, but the principle of division once settled would be permanent. A vast amount of litigation would be thus saved, and in the end all parties would find it much more satisfactory than the present blindfold system.

INDEX.

CORRECTIONS.

Page 198, 4th line from bottom, *read* brick, masonry, or of iron
„ 201, line 15, *for* prevent *read* present
„ 239, line 7 from bottom, *for* pressure-gauge *read* pressure-indicator
Same page, line 10 from bottom, *for* pressure-gauges *read* pressure-indicators

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